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Poverty and Access to Roads in Papua New Guinea *

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Abstract

In this paper, our overall goal is to understand how effective access to infrastructure, especially roads, 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 roads, measured as traveling time from a community to the nearest road. In our analysis, we test whether or not access to infrastructure is a significant factor in a household's poverty status in order to better 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 average years of schooling and literacy leads to declines in poverty. Increasing access to roads is also found to reduce poverty. The results are robust to the way that we measure consumption, set the poverty line, run our experiments, and control for the possible endogeneity of access to roads in the consumption equation.

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Poverty and Access to Roads 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.[2] 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.[3] One is that poor areas that have had the least access to infrastructure in the past may have high benefits from new investments. Another argument is that in some countries it is possible that the poor are concentrated in sectors of the economy in which rates of return to infrastructure would be high if investments were made. [4]

The Papua New Guinea (PNG) economy provides a unique opportunity to study the effect of access to infrastructure on poverty. Because of PNG's 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.[5] In cities and some better-off rural areas, residents 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 more comparable to other developing countries in terms of some metrics (e.g., meters of roads per person or per square kilometer), access to many social services is still limited mainly because the road system is poorly maintained, it is highly fragmented in some areas, 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 demonstrate 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 narrow the scope of our analysis, we focus on access to roads in rural areas 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. Finally, we believe access to roads and the distance between the point at which villagers can gain access to the road and the nearest government station (which is usually the center of economic activity in many districts) can best proxy for the level of infrastructure. In our analysis, however, we allow for the possibility that access to roads is endogenous and correct for the potential endogeneity by using an instrumental variable approach to estimating the model.

To meet our 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 following 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 in PNG and presents result about the effect that access to infrastructure has on the poor. We simulate the impact of various investment strategies on poverty. Our modeling and simulation sections draw heavily on the work of Datt and Jolliffe.[6] The final section concludes.

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.[7] 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 (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.[8] 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 documented the usual mode of travel, which in rural areas, was almost exclusively by foot.[9]

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.[10] 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. Moreover, an analysis of covariance suggested that regional effects in the prices of items in the food poverty line were more important than sectoral (urban/rural effects).[11] Thus, estimating poverty lines just for urban and rural areas would leave a substantial amount of uncontrolled price variation.

The poverty lines used in our study were based on baskets of locally consumed foods that provide 2200 calories per day. A comparison of the food budgets of poor households in each region showed that a single national basket of foods was inappropriate, so separate baskets of foods were used for the NCD, the Highlands, and the lowland regions. To ensure that these baskets provided diets of the same quality, they were formed from the food budgets of households living below the same level of real expenditure per adult-equivalent, rather than from the poorest x

percent of households in each region.[12] Thus, differences in real consumption levels between regions did not translate into differences in the poverty line diets. Furthermore, revealed preference tests were carried out by checking if the cost in region *j* of buying the region *i* basket of foods was less than the cost of buying the region *j* basket of foods, at region *j* prices.[13] The tests provided no evidence that any region had a poverty line diet that was inferior to that of the other regions. The annual cost of the poverty line diets varied from K543 in the NCD to K218 in the North Coast region, with a national average of K300.[14]

The final value of the poverty lines was set by adding an allowance for non-food items. This allowance is based on the typical value of non-food spending by households whose total expenditure equals the cost of the food poverty line. Consuming these non-food items means that some food needs are ignored, so the non-food items can be considered as essentials.[15] The average food share for households whose total expenditure equals the food poverty line is found from the following Engel curve:

$$w = a + b \ln\left(\frac{x}{n \cdot z_j^F}\right) + \sum_{k=1}^{K} g_k n_k + \sum_{j=1}^{J-1} f_j D_j + e$$

where *w* is the food budget share, *x* is total expenditure, *n* is the number of persons, z_j^F is the food poverty line for an adult-equivalent in region *j*, n_k is the number of people in the *k*th demographic category, and D_j is an intercept dummy for region *j*. If total expenditure equals the cost of the food poverty line, $\ln\left(x/\left(n \cdot z_j^F\right)\right) = 0$, so $a_j = \hat{a} + \sum_{k=1}^{K} \hat{g}_k \bar{n}_k + \hat{f}_j$ gives the average food share in region *j*, where $\bar{n}_k$ is the mean of the demographic variables for the households used to form the poverty line basket of foods. The poverty line z_j is given by the sum of the food and non-food components, $z_j = z_j^F + z_j^F(1-a_j) = z_j^F(2-a_j)$. This ranged from K779 in the NCD to K280 in the North Coast, with a national average of K400 (making the estimate of the size of the non-food allowance K100 or one-quarter of the poverty line).

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.[16] 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 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.[17]

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). The standard errors for these estimates (2.9 and 3.6 percent) suggest that these differences in sectoral poverty rates are highly significant.[18] Overall (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). The rural poor account for 94.3 percent of PNG's poor, making it clear that poverty in PNG is a rural problem. This inference is also borne out by other indicators from the survey, with the stunting rate for young children in rural areas being almost 2.5 times that of children in urban areas (47.0 vs 19.8 percent).[19]

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).[20] 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.[21] This index (3.9 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.

(Table 1 about here)

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 much larger household survey than the one conducted in 1996. Instead, the poverty comparisons presented here are for the five major geographical and urban regions of the country -- the Papuan/South Coast; the Highlands; Momase/North Coast; the New Guinea Islands; and the National Capital District (NCD). The map in Figure 1 illustrates the location of these areas.

(Figure 1 about here)

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 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’s regions is closely correlated with 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 Highlands and Momase/North Coast, the record on education and health is also not good in the Papuan/South Coast region.

(Table 2 about here)

Given the remoteness and rugged terrain of PNG, poor access to roads may be one of the proximate causes of the 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, on average, 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).

(Table 3 about here)

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 must 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).

(Table 4 about here)

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 2). A one-hour increase in travelling time to the nearest transport facility reduces real consumption by almost 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.

(Figure 2 about here)

While there may be a number of aspects of access to infrastructure that affect consumption (for example, see Jacoby[22]), our sample data clearly illustrate two. First, access to a road affects the price farmers receive for their crops and the prices that households must pay for their purchased food (Figure 3). The relationship between the average price of sweet potato (which is the national staple and a widely marketed food), 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.[23] 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.

(Figure 3 about here)

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) of a one kilogram packet of Trukai rice. This imported food was one of the most widely available foods in trade stores across PNG in 1996. Figure 4 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 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).[24]

(Figure 4 about here)

Second, 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 not only increases income, it can help to stabilise the cash incomes of households, and in this manner reduce vulnerability. . 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.[25] 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).

(Table 5 about here)

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 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.[26]

A common approach to the multivariate analysis of poverty is to define a 0-1 variable; $h_i = 1$ if the ith household's per capita consumption expenditure, c_i is less than the poverty line, z and proceed with probit estimation:[27]

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

where Φ is the standard cumulative normal, and $\mathbf{X}$ is the matrix of explanatory variables. Usually interest is not centered on the coefficient vector $\mathbf{b}$ but on the 'probability derivatives,' which can be obtained from **b** and can 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 in which binary response models are used, the underlying variable that generates h_i is fully observed. 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 $\mathbf{x}_i$ using an estimator such as Ordinary Least Squares (OLS) – whilst making weaker assumptions about the errors than are needed by probit models.[28]

Rather than using poverty probits, the approach of this paper is to model the determinants of consumption using OLS and instrumental variable (IV) techniques, 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":[29]

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

where we initially treat u_i as uncorrelated with $\boldsymbol{x}_i$, but then relax that assumption and use an IV procedure to guard against the case where u_i and $\boldsymbol{x}_i$ are correlated. 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, $\hat{s}$:

$$\text{prob}(\ln(\hat{c}_i/z)) < 0 = \Phi\left(\left(-\mathbf{x}_i\hat{\mathbf{b}}\right)/\hat{s}\right).$$ [30]

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. [31]

Model Specification

A wide range of variables measuring the potential determinants of rural poverty is available from the survey and these are described under the following six headings: demographics, education, employment and occupations, assets, community characteristics, and geo-climatic characteristics. 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 use value of durable goods and dwellings is already included as a component of consumption.

With these variables available, we specify the following model:

(1) Consumption= f (infrastructure and human capital characteristics, household demographics, employment and occupation, assets, and environmental variables)

The main explanatory variables of interest, the infrastructure-related variables (and especially the variable that measures access to roads), were created by asking community leaders about the average time that it took, with the most commonly used method of transportation (in almost all cases, walking), to travel from the center of the PSU to various locations. There are at least two possible sources of measurement error in this variable: travel times less than two hours were based on a categorical variable (0-30 minutes, 30-60 minutes, 60-120 minutes), and the time from the center of the PSU will not correspond with the time from any particular household, especially in some of the more dispersed communities. Consequently, we use an IV approach to guard against any measurement error problems affecting the inferences.

We were also concerned that the distance to the road, while important, does not capture all of the relevant differences in access to infrastructure among villages. It is possible that although two villages are situated such that they are the same distance from a road, once the villagers get to the road, those is one village have to travel further to the center of economic activity than those of the other. To capture this additional effect, we specify a variable (ROAD-STATION) that measures the "extra" distance from the road to the government station, the headquarters of the district government and in most cases the location of the region's main markets and social services. We also specify an index of market development, based on the combined number of trade stores, public transport businesses and fresh produce markets located in the PSU. The index of market development is designed to capture the notion that missing markets prevent households from gaining from specialization, thereby reducing living standards (e.g., minimizing involvement in cash cropping because of concerns about food market failures).[32]

In addition to the infrastructure variables, we also created a number of variables that measure important factors that affect household expenditures. Most importantly for our analysis, we create a number of variables to measure the household's human capital. Specifically, 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. Finally, Appendix A contains a description of the remaining variables that we use in our analysis to control for household demographics, employment and occupation, assets, and agro-climatic effects, while Table 6 contains summary statistics for the variables in the model.

(Table 6 about here)

Estimation Strategy

One potential problem with estimating equation (1) is that the coefficient on the variable measuring traveling time to roads could be biased since it is possible that it may not only be the effect of roads on income that is being picked up but the reverse effect of income on roads. If areas with higher expenditures (i.e., richer areas) also attract investment in roads (while those with high levels of poverty do not attract investment), part of the effect of the better environment could be picked up by the access-to-roads variable. To address this, in part, we can try to add variables that control for the productivity potential of a given area (in order to "soak up" the unobserved heterogeneity). It is for this reason that we include five geo-climatic variables (see Appendix A).

Despite including a number of control variables as a way to control for the unobserved heterogeneity, it likely is difficult, if not impossible, to control for all factors that affect productivity. In order to address the statistical problem that there may also be causation from poverty to roads we constructed a new variable that we can use as an instrumental variable (IV).[33] . To do this, we need a variable that explains roads, but does not explain consumption except through its impact on roads. The variable used (henceforth named JOINNET) measures the year in which the PNG national highway system penetrated into each of PNG's districts (equivalent to a county in the United States – of which there are 87 in PNG). Our assumption is that having a national highway enter a district should stimulate the building of feeder roads, and in this way reduce the traveling time to the nearest road. Thus, those districts that have had a national highway for a longer time are likely to have a larger network of feeder roads and households in those areas should face shorter travel times.

The key “statistical” feature of JOINNET, however, is that it is not necessarily correlated productivity (independent of its effect on the building of feeder roads). We argue that JOINNET has this characteristic since the year in which the national road network reaches any given district is in many respects an “accident of geography” (since the national highway in PNG typically started at the coast and proceeded inland). The penetration of PNG’s national road network into the Highlands region provides an example of this pattern. The national highway first entered the main districts of Eastern Highlands Province (a province that contains 8 districts) in 1961. But it was not until 1966 that the national highway network reached most of the main districts of Western Highlands Province (a province that contains 7 districts), in part, because it first had to be built through Eastern Highlands Province and another adjacent province before it could reach Western Highlands. The important thing for our analysis is that this timing is a function of the location of any given province or district, as in the case of Eastern Highlands Province which is closer to Lae (the largest city on PNG’s north coast and the beginning point of the Highlands Highway) than is Western Highlands Province. Moreover, and just as important, the timing of the highway penetration into a region is not a function of the region’s wealth or productivity. For example, on a scale of 1 (poor) to 5 (high), the agricultural potential (or productivity) of the main districts in Western Highland Province (4.83—a score that means the Province has very high agricultural production potential) is much greater than those of Eastern

Highland Province (which has an agricultural productivity index of 3.00 or only has moderate potential).[34]

With a variable such as JOINNET, we can adopt an IV approach by first using JOINNET to help explain variation in the traveling time to roads variable, and then the predicted values from this equation can be inserted into equation (1). If the instrument performs its role, the coefficient on the variable measuring access to roads will be purged of bias due to both endogeneity and measurement error.

Results from the Determinants of Consumption Analysis

The results of the basic model of rural consumption estimated using OLS (for the time being ignoring the possible implications of the endogeneity of traveling time to the nearest road) are reported in Table 7, column 1.[35] In general, the model performs well. The goodness of fit measure, R^2, is 0.35, sufficiently high for models using cross sectional household data. In addition, many coefficients of our control variables are 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.[36] 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, the pattern of geo-climatic variable is also reasonable: consumption is lower for households living in areas characterized by steep slopes, for those in which the land is subject to inundation, and for those with rainfall that is subject to periodic shortfalls.[37]

Even after controlling for the demographic, educational, employment and environmental factors, the variable measuring access to roads has a negative and significant coefficient. In particular, as travel time to the nearest road increases (or access decreases), 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.

(Table 7 about here)

Of course, whether having proximity to a road is valuable may depend on what that road leads to. In order to explore this issue, the model was re-specified to include ROAD-STATION, the variable that measures the difference in traveling time from the nearest road to the nearest government station. The results show that those households that may be the same distance from a road, but are further from a government station, have lower consumption, although the effect is not statistically significant (Table 7, column 2).[38]   The inclusion of this variable, however, not only does not weaken the access to roads effect, it makes it slightly stronger. In either the model in the first or second column of Table 7, the results support our hypothesis that improving access to transport infrastructure will raise rural consumption.

When traveling time to the nearest road is treated as an endogenous variable, the performance of the estimation, if any thing, become stronger and the results largely confirm the previous inferences—lowering travel time from the village to the nearest road raises consumption (Table 7, column 3).   However, while most of the coefficients of the control variables remain the same in terms of magnitude and significance, the coefficient on the roads variable more than doubles in absolute magnitude.[39]   The larger negative effect of access-to-roads when IV is used suggests that in PNG the causation from wealth to roads is relatively unimportant. Instead, assuming the IV approach is valid, the rise in the absolute value of the coefficient is consistent with the observation that perhaps the coefficient in column (1) was suffering from attenuation bias due to measurement error.[40]

While the results in columns (1) to (3) of Table 7 appear to provide firm support for the hypothesis that road access affects consumption and poverty, the possibility remains that uncontrolled price variation *within* regions is causing the results. The deflation by the poverty line has only controlled for price variation between regions, but it is apparent from Figures 3 and 4 that prices will also vary with road access within regions. Therefore, in order to make pure welfare comparisons among areas, we need to isolate the effect of access to roads on consumption separately from that of the effect of access on prices. To do so, we re-calculated the food poverty line, separately for each individual community, and used this as a deflator for real consumption. The results of re-estimating the model using this new dependent variable are in column (4) of Table 7. When we use this new variable, which has a higher variance than the original welfare ratio (the one adjusted by a regional price deflator), the general performance of the model deteriorates somewhat. Specifically, the R^2 statistic and *t*-ratios of a number of variables fall. However, the sign, magnitude and significance of the instrumental variables estimate of the coefficient on the access to roads variable is unaltered, and if anything, its magnitude actually rises somewhat.[41]

Poverty Alleviation and Investments in Infrastructure

Table 8 reports the results of various poverty simulations done with the model in Table 7, column 1 (although we also report the results of a simulation for the model in column 3). The beneficial effect of increasing literacy, schooling and access to 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 3.04 percent (row 4), following a one year rise in average school years per adult, if the average schooling in rural 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. 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).

(Table 8 about here)

Increasing access to roads also has an independent effect on decreasing poverty. Using the coefficient on the access-to-roads variable from Table 7, column 1, the headcount index would fall by 5.36 percent if the travelling time to the nearest road could be cut to 3 hours for those communities where the road is currently, on average, more than 3 hours away (Table 8, row 5). Cutting the travel time to two hours drops the headcount marginally more (by 5.77 percent—row 6). The poverty gap and severity indices drop more (columns 2 and 3). Although we do not show it in Table 8, the magnitude of the fall in the headcount index more than doubles (falling by 11.84 percent), when we use the IV coefficient on the traveling time to roads variable from Table 7, column 3. Clearly, however, regardless of the nature of the poverty experiment (cutting the access to road by 2 or 3 hours) and no matter from what equation we take the coefficient for the poverty simulation, reducing traveling time to key social services and economic activity by bringing the road network closer to PNG's villages is likely to reduce poverty.

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.

Appendix A

Definition of Control Variables Used in Poverty Analysis of PNG

In this appendix, we provide an explanation of the control variables that we use in our analysis of the determinants of expenditures. The discussion of the main variables of interest, the infrastructure variables and the human capital variables are in the text in Section IV.

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 consumption within households, although attention has been paid to the differing costs of children and adults.[42]

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.

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. Similarly, factors that can make it difficult to build roads, such as steep slopes and waterlogged and inundated soils, can also reduce the agricultural potential and lead to lower expenditures. To control for these factors we include five geo-climatic factors in the model—the elevation (measured in meters); a dummy variable that equals one if the average slope of the land in the area of the sampling unit is greater than 10 percent; a dummy variable that equals one if the land is susceptible to flooding; a dummy variable if the sampling unit is not susceptible to periods of severe rainfall deficits; and the annual level of rainfall (1000 mm). The data for these variables come from Papua New Guinea Resource Inventory System (PNGRIS) and are available for each resource mapping unit (RMU) in PNG.[43]

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.	16.3 (4.3)	3.0	3.8 (1.4)	2.3	1.4 (0.7)	1.9	5.5
Papuan/South Coast	30.0 (5.9)	14.8	9.8 (2.8)	16.1	4.3 (1.5)	16.4	14.9
Highlands	26.0 (4.0)	34.6	8.0 (1.7)	35.1	3.4 (0.9)	34.7	40.1
Momase/North Coast	38.8 (5.0)	37.5	11.2 (2.4)	35.9	5.0 (1.5)	36.9	29.2
New Guinea Islands	29.8 (6.4)	10.2	9.3 (3.1)	10.5	3.8 (1.8)	10.1	10.3
PNG	30.2 (2.5)	100.0	9.1 (1.1)	100.0	3.9 (0.6)	100.0	100.0
Urban	11.4 (3.6)	5.7	2.2 (0.7)	3.7	0.7 (0.3)	2.6	15.1
Rural	33.5 (2.9)	94.3	10.3 (1.3)	96.3	4.5 (0.7)	97.4	84.9

Source: Authors' Household Survey.
Note: Standard errors in ( ). Results are corrected for the effect of clustering, sampling weights and stratification.

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 Poor 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 Index (%)	Headcount Contribution to total (%)	Poverty gap Index (%)	Poverty gap Contribution to total (%)	Poverty severity Index (%)	Poverty severity Contribution to total (%)	Share of total pop (%)
Rural PNG	**33.5** **(2.9)**	**100.0**	**10.3** **(1.3)**	**100.0**	**4.5** **(0.7)**	**100.0**	**100.0**
Road < 30 minutes	29.8 (3.4)	58.6	8.6 (1.5)	55.1	3.6 (0.9)	53.0	65.9
30 ≤ road < 60 minutes	18.2 (8.5)	5.4	4.6 (2.2)	4.5	1.9 (1.1)	4.4	10.1
60 ≤ road < 120 minutes	56.7 (9.2)	11.4	19.3 (3.6)	12.5	8.7 (2.3)	13.0	6.7
120 minutes ≤ road	47.6 (5.8)	24.6	16.6 (2.9)	27.8	7.7 (1.7)	29.6	17.3
School < 30 minutes	31.2 (4.0)	48.7	10.3 (2.0)	52.2	4.8 (1.1)	55.3	52.4
30 ≤ school<60 minutes	22.8 (6.2)	14.8	6.7 (2.4)	14.1	3.0 (1.4)	14.4	21.7
60≤school<120 minutes	49.0 (5.3)	20.1	12.2 (2.0)	16.1	4.1 (1.0)	12.4	13.7
120 minutes ≤ school	45.0 (7.1)	16.4	14.9 (3.2)	17.6	6.6 (1.9)	17.8	12.2

Note: "School" refers to community (or elementary) schools.
Standard errors in ( ). Results are corrected for the effect of clustering, sampling weights and stratification.

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
Traveling time to nearest road (hours)	3.215	7.275	0.25	30
Traveling time (Govt. Station minus Road)	0.576	5.080	-23	38
Geo-climatic variables				
Elevation ('000 metres)	1.053	0.731	0.3	2.6
Dummy: Slope > 10 degrees	0.680	0.467	0	1
Dummy: land inundation occurs	0.234	0.424	0	1
Dummy: Rainfall deficit is rare	0.332	0.471	0	1
Annual rainfall ('000 mm)	2.707	0.728	1.25	4.5

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, the PSU is in a resource mapping unit with slope less than 10 degrees, no land inundation and subject to a seasonal rainfall deficit.

[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.

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

	Roads Exogenous		Roads Endogenous	
	(1)	(2)	(3)	(4)
Demographics				
Household size	-0.117	-0.116	-0.113	0.022
	(3.45)**	(3.40)**	(3.08)**	(0.58)
Household size, squared	0.005	0.005	0.004	-0.002
	(3.30)**	(3.32)**	(2.65)*	(0.95)
Number below age 15	-0.056	-0.058	-0.058	-0.017
	(2.45)*	(2.57)*	(2.41)*	(0.47)
Number above age 50	0.011	0.007	-0.020	0.021
	(0.24)	(0.15)	(0.37)	(0.27)
Age of household head (years)	-0.009	-0.010	-0.010	0.004
	(0.87)	(0.92)	(0.93)	(0.33)
Squared age of household head	0.000	0.000	0.000	-0.000
	(0.77)	(0.75)	(0.69)	(0.58)
Dummy: Female-headed household	-0.089	-0.090	-0.149	-0.092
	(0.94)	(0.96)	(1.50)	(0.71)
Education, employment & occupation				
Dummy: Household head is literate	0.206	0.196	0.187	0.078
	(3.66)**	(3.53)**	(3.58)**	(1.14)
Average years of schooling of adults	0.021	0.020	0.008	-0.014
	(1.68)+	(1.65)	(0.58)	(0.72)
Dummy: Head's income from minor sources	-0.333	-0.340	-0.360	0.074
	(2.99)**	(3.10)**	(3.12)**	(0.41)
Dummy: Head is tree crop farmer	-0.101	-0.098	-0.064	0.073
	(1.26)	(1.24)	(0.81)	(0.76)
Dummy: Head is in formal sector	0.356	0.349	0.388	0.108
	(3.61)**	(3.60)**	(4.32)**	(1.05)
% of adults with no cash income sources	-0.079	-0.046	0.131	0.314
	(0.80)	(0.45)	(0.83)	(1.51)
Assets				
Dummy: Owns agricultural capital goods	0.266	0.269	0.272	-0.031
	(4.23)**	(4.31)**	(4.21)**	(0.45)
Number of pigs owned	0.012	0.012	0.010	0.013
	(1.55)	(1.48)	(1.26)	(1.24)
Community characteristics				
Traveling time to nearest road (hours)[a]	-0.014	-0.017	-0.040	-0.053
	(3.20)**	(3.58)**	(2.19)*	(2.18)*
Index of market development	0.000	-0.000	-0.007	-0.003
	(0.02)	(0.06)	(0.84)	(0.28)
Traveling time (Govt. Station minus road—ROAD-STATION)		-0.010		
		(1.34)		

Geo-climatic variables				
Elevation (‘000 metres)	0.129	0.116	0.155	0.199
	(1.71)+	(1.55)	(1.90)+	(2.27)*
Dummy: Slope > 10 degrees	-0.484	-0.485	-0.489	-0.394
	(5.58)**	(5.73)**	(5.55)**	(3.14)**
Dummy: land inundation occurs	-0.189	-0.206	-0.212	-0.193
	(1.79)+	(1.96)+	(1.94)+	(1.32)
Dummy: Rainfall deficit is rare	0.453	0.450	0.481	0.202
	(3.35)**	(3.35)**	(3.29)**	(1.29)
Annual rainfall (‘000 mm)	-0.292	-0.287	-0.294	-0.172
	(3.44)**	(3.45)**	(3.43)**	(2.10)*
Intercept	1.950	1.991	2.096	1.273
	(5.06)**	(5.25)**	(5.62)**	(3.32)**
Poverty line used to deflate consumption:	Regional	Regional	Regional	Community
R^2	0.353	0.357	0.314	0.051
Standard error of disturbances (σ)[b]	0.613	0.612	0.613	0.699
Zero-slopes *F*-test[c]	10.90**	10.77**	11.77**	1.73+

Note: Results corrected for the effect of clustering, sampling weights and stratification; + significant at 10%; * significant at 5%; ** significant at 1%. For notes on definition of variables see Table 6.

[a] Treated as endogenous in columns (3) and (4), with “Year joined” used as the instrumental variable.

[b] 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.

[c] 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).[44] In column (1), (3), and (4) the degrees of freedom are $_{(22,39)}$ and in column (2) $_{(23,38)}$.

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	32.59	11.27	5.39
Increase literacy rate of household heads to 100 percent	27.21 (-16.52)	8.85 (-21.48)	4.05 (-24.79)
Increase household average school years per adult by one year	31.60 (-3.04)	10.83 (-3.89)	5.15 (-4.48)
Decrease traveling time to road to 3 hours for communities where currently > 3 hours	30.85 (-5.36)	10.35 (-8.19)	4.83 (-10.27)
Decrease traveling time to road to 2 hours for communities where currently > 2 hours	30.72 (-5.77)	10.29 (-8.74)	4.80 (-10.90)

Note: Each simulated change is considered in isolation of the other changes. The model used to predict poverty is reported in Table 7, column (1). The percent change from base is calculated from the *predicted* baseline values.

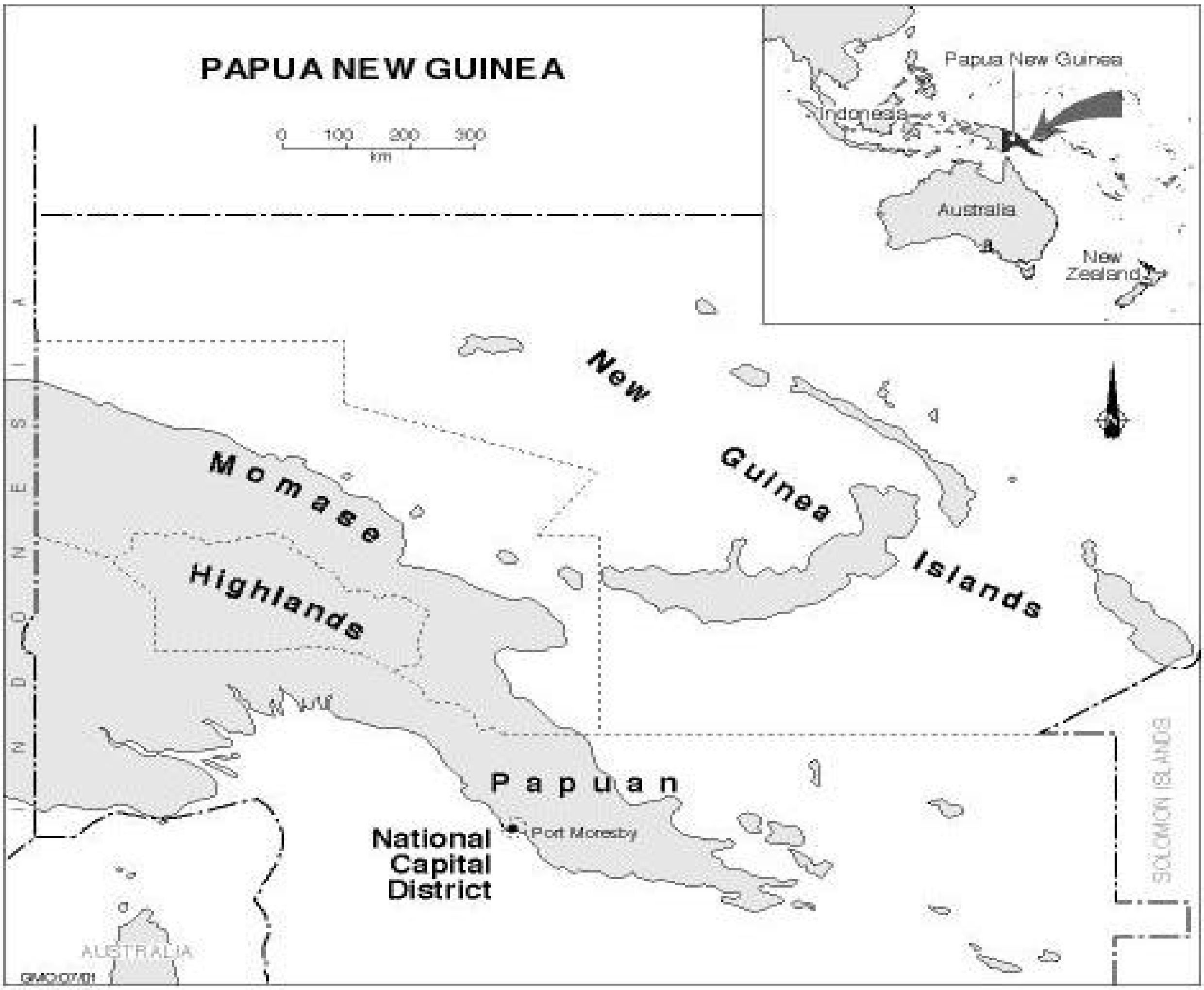


Figure 1. Map of Papua New Guinea

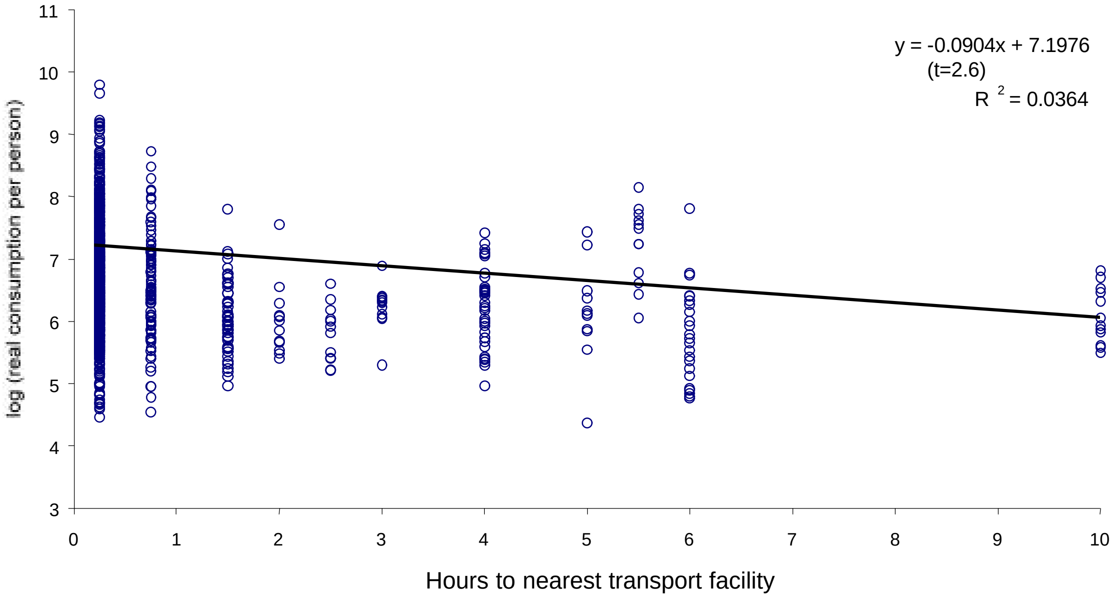
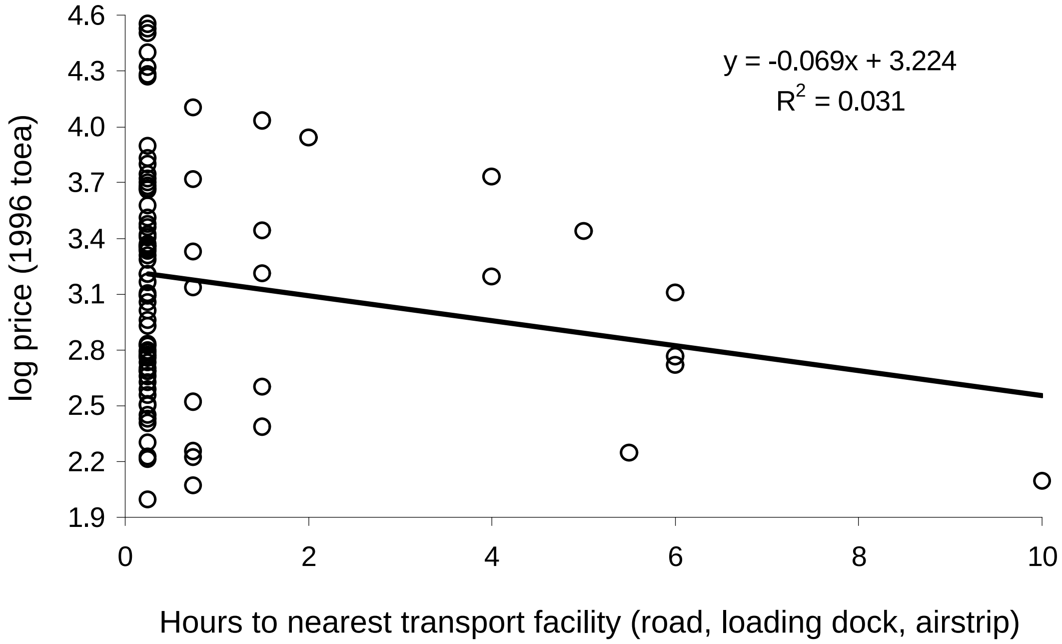
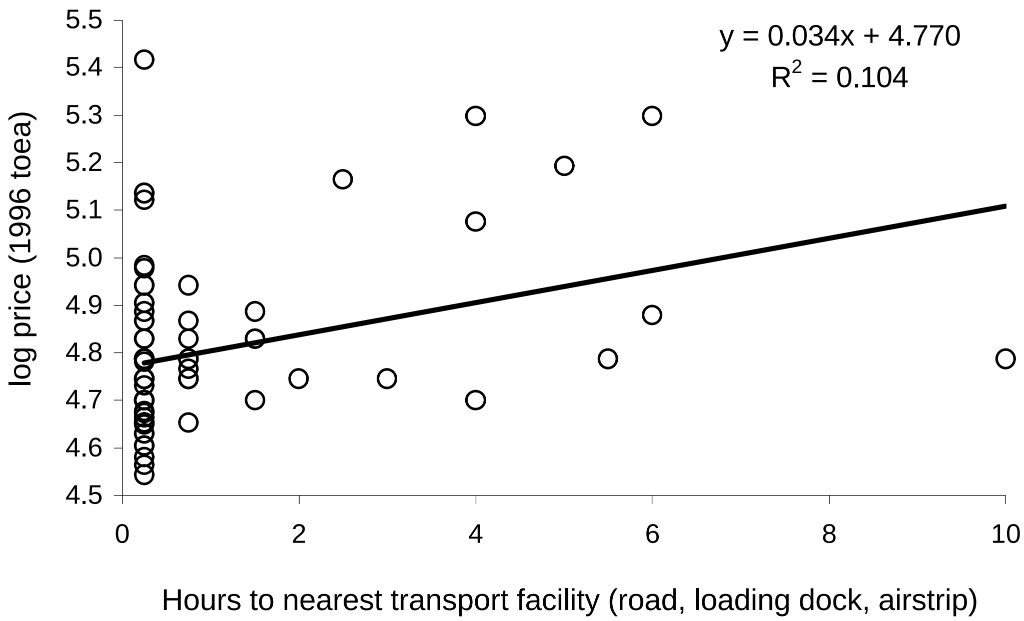


Figure 2. Consumption and Access to Transportation in PNG in 1996



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

Figure 3. Effect of Access to Transport Facilities on Price of Sweet Potato



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

Figure 4. Effect of Access to Transport Facilities on Consumer Price of Rice

Notes

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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, Hans Binswanger, Shahidur Khandker, and Mark Rosenzweig, "How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India," Journal of Development Economics 41 (August 1993): 337-66; World Bank, World Development Report 1994: Infrastructure for Development, (Washington, D.C: World Bank, 1994); Dominique van de Walle and Kimberley Nead, Public Spending and the Poor: Theory and Evidence (Washington, DC: Johns Hopkins University Press and the World Bank, 1995); Hanan G. Jacoby, "Access to Markets and the Benefits of Rural Roads," The Economic Journal 110 (July 2000): 713-37; Dominique van de Walle, "Choosing Rural Road Investments to Help Reduce Poverty," World Development 30 (April 2002): 575-89.

2.World Bank, Infrastructure for Development

3. Micheal Lipton and Martin Ravallion, "Poverty and Policy," Handbook of Development Economics, eds. Jere Behrman and T.N. Srinivasan, (Amsterdam: North-Holland, 1995).

4. van de Walle, "Choosing Rural Road Investments to Help Reduce Poverty,"; Shenggen Fan, Peter Hazell and Sukhadeo Thorat, "Linkages between Government Spending, Growth, and Poverty in Rural India," (Research Report 110, Washington, D.C.: International Food Policy Research Institute, 1999).

5. World Bank, Papua New Guinea: Poverty and Access to Public Services, (Washington, D.C.: World Bank, 1999). 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, "Access to Markets and the Benefits of Rural Roads," 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 5 million people, the population is home to 850 separate languages, one-seventh of the world's total. See Barbara Grimes, <u>Ethnologue: Languages of the World</u>, (Dallas, TX: Summer Institute for Linguistics, 1992).

6. Gaurav Datt and Dean Jolliffe, "Determinants of Poverty in Egypt," (Discussion Paper No. 75, Washington D.C., International Food Policy Research Institute, 1999).

7. This was established from an agricultural mapping project. See Bryant Allen, Michael Bourke and Robin Hide, "The Sustainability of Papua New Guinea Agricultural Systems: the C <u>Global Environmental Change</u> 5 (September 1995): 297-312.

8. In order to generate a value for foods that were self-produced, enumerators asked respondents to provide an estimate for how much each self-produced item was worth. Since such estimates may be subject to reporting error, we wanted to make sure that using respondent-reported unit values (the value of the production divided by the quantity of production) did not produce biased estimates of expenditure. As a robustness check, we find that the estimate of average expenditure for the sample is unchanged if the respondent-reported values are replaced by either the cluster medians of the unit values or the cluster averages of market prices. See John Gibson and Scott Rozelle, "Results of the Household Survey Component of the 1996 Poverty Assessment for Papua New Guinea," (Discussion Paper, Poverty and Human Resources Division, Washington D.C., World Bank, 1999).

9. 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 (n. 1 above) 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.

10. Martin Ravallion, <u>Poverty Comparisons</u>, (Chur, Switzerland: Harwood Academic Publishers, 1994).

11. World Bank, <u>Papua New Guinea: Poverty and Access to Public Services</u>.

12. The adult-equivalence scale counts children aged 0-6 years as 0.5 adults and all others as 1.0. This figure is based on averaging the estimates of the cost of raising a child produced by the Engel (0.58) and Rothbarth methods (0.24) and a comparison of the daily calorie requirements of adults and children (0.62). Hence, the average of 0.58, 0.24 and 0.62 is 0.48, which is rounded to 0.50 in the paper. Details are provided by Gibson and Rozelle, "Results of the Household Survey Component of the 1996 Poverty Assessment for Papua New Guinea." According to Deaton and Muellbauer, the Engel method provides an upper bound and the Rothbarth method a lower bound to the true equivalence scale, and our estimate of 0.5 obeys this condition. See Angus Deaton and John Muellbauer, "On Measuring Child Costs: with Applications to Poor Countries," Journal of Political Economy 96 (August 1986): 720-43.

13. If the cost was less it would suggest that the region *i* basket of foods was less preferred than the region *j* basket, which would indicate that the region *i* poverty line gave a lower standard of living.

14. The food poverty lines are slightly higher, and more variable between regions, if a single national basket of foods is used. Note that K1.30=US$1.00 in 1996.

15. Ravallion, Poverty Comparisons.

16. World Bank, Papua New Guinea: Poverty and Access to Public Services.

17. Michael Baxter, Enclaves or Equity: The Rural Crisis and Development Choice in Papua New Guinea, (Canberra: Australian Agency for International Development, 2001).

18. These standard errors correct for weighting, clustering and stratification, using the program of Jolliffe and Semykina. See Dean Jolliffe and Anastassia Semykina, "Robust Standard Errors for the Foster-Greer-Thorbecke Class of Poverty Indices: SEPOV," (Stata Technical Bulletin, STB-51, September 1999).

19. Stunting is defined as height more than two standard deviations below the median height for that age and gender in the reference population used by the National Center for Health Statistics.

20. 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 K160 million of perfectly targeted (and costless) transfers to eliminate poverty in PNG. Another interpretation of the poverty gap is that it can also be written as the product of the headcount index and the income gap, where the income gap is the average shortfall of the poor as a fraction of the poverty line. This means that in the case of PNG, the average shortfall is 30 percent of the poverty line.

21. 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 (James Foster, Joel Greer and Eric Thorbecke, "A Class of Decomposable Poverty Measures," Econometrica 52 (May 1984): 761-765 – hereafter FGT). The equation is:

$$P_a = \frac{1}{n}\sum_{j=1}^{q}\left(\frac{g_j}{z}\right)^a$$

where the poverty line is z, the value of expenditure per capita for the jth person's household is xj and the poverty gap for individual j is gj = z - xj. Total population size is n and q is the number of poor people (those where xj < z). When parameter α is set to zero, P0 is simply the headcount index. When α is set equal to one, P1 is the poverty gap index, and when α is set equal to two, P2 is the poverty severity index.

22. Hanan G. Jacoby, "Access to Markets and the Benefits of Rural Roads."

23. 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.

24. 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).

25. 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. For a more complete and detailed argument, see John Gibson, "Food Security and Food Policy," (Discussion Paper, Papua New Guinea of Institute of National Affairs, Port Moresby, 2001). It should be noted that a reduction in variability, holding the mean constant, would not necessarily affect the FGT measures. Reducing the variability of income is more related to the dynamics of poverty.

26. Martin Ravallion, “Poor Areas,” Handbook of Applied Economic Statistics, eds. A. Ullah and D. Giles (New York: Marcel Dekker, 1998).

27. Examples include Bardhan, Gaiha and Grootaert. Gibson also uses this approach, for PNG urban poverty in the mid-1980s. See Pranab Bardhan, Land, Labour and Rural Poverty: Essays in Development Economics, (New Delhi: Oxford University Press, 1984); Raghav Gaiha, “On Measuring the Risk of Rural Poverty in India,” Rural Poverty in South Asia, eds. T. N. Srinivasan and Pranab Bardhan, 219-261 (Irvington, N.Y.: Columbia University Press, 1988); Grootaert, “Determinants of Poverty in Côte d'Ivoire in the 1980s”; John Gibson, “Identifying the Poor for Efficient Targeting: Results for Papua New Guinea,” New Zealand Economic Papers 32 (June 1998): 1-18.

28. Martin Ravallion, “Poor Areas.”

29. Charles Blackorby and David Donaldson, “Welfare Ratios and Distributionally Sensitive Cost-Benefit Analysis,” Journal of Public Economics 34 (December 1987): 265-90.

30. In this part of the paper, we draw heavy on the methodology of Datt and Jolliffe, “Determinants of Poverty in Egypt.” One complication with this procedure is that to get an estimate of the standard error of the regression when the data do not come from a simple random survey, it may be necessary to use a pseudo-maximum likelihood estimator (C. J. Skinner, D. Holt and T.M.F. Smith, Analysis of Complex Surveys (New York: Wiley, 1989). The reason is that the usual regression estimator for clustered, stratified 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.

31. Gaurav Datt, “Simulating Poverty Measures from Regression Models of Househol (Discussion Paper, International Food Policy Research Institute, Washington D.C., 1998).

32. In a previous version of the model, we also included a variable that measured traveling time to a set of public services (e.g, aid post and secondary schools). This variable, however, is highly correlated with the variable measuring the distance from the government station (r=0.87) and so it is not included in the specification used in this paper.

33. We are grateful to members of the Department of Human Geography of Australian National University for assistance with the construction of this variable.

34. Luke Hanson, Bryant Allen, Michael Bourke and Tess McCarthy, Papua New Guinea Rural Development Handbook (Canbera: The Australian National University, 2001).

35. 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. See World Bank (n. 5 above).

36. The coefficient on the years-of-schooling variable needs to be interpreted with care because it is possible that the omission of a variable to hold ability constant is overstating the effect due to schooling.

37. For both elevation and rainfall, a quadratic term was included in alternative specifications, but neither were significant.

38. In an alternative specification, when the government station is closer than the road (i.e., for those 46 observations in which the value of the Station-Road variable is negative) the value of the observation is set to zero. In this specification, the coefficient on Station-Road is negative and significant, a plausible result meaning that improving travel time after villagers reach the road will also improve consumption. Moreover, regardless of what is done to the ROAD-STATION variable, there is little effect on the coefficient of the access-to-roads variable.

39. In the first stage regression, the coefficient on the JOINNET variable in the equation explaining traveling time to roads is positive and highly significant; the earlier (later) the national road network penetrated into a district, the lower (higher) the travel time. The addition of JOINNET raises the R^2 of the first stage regression from 0.34 to 0.43 and the F-test for excluding the instrument is highly significant, $F_{(1,60)}=8.38$.

40. However, the difference between the column (1) and column (3) results falls outside the usual levels of statistical significance, according to a Hausman test (t=1.60, p<0.12).

41. The (unreported) OLS estimates are also largely unchanged from their value in column (1) when the community-level deflator is used.

42. Peter Lanjouw and Martin Ravallion, “Poverty and Household Size,” The Economic Journal 105 (November 1995): 1415-1434.

43. There are at least 4000 RMUs in PNG, which provide fairly detailed information about the geo-climatic information for each sampling unit in our sample. The value assigned to each sampling unit is the value of the variable for the nearest RMU.

44. StataCorp, Stata Statistical Software: Release 6.0 (College Station, TX: Stata Corporation, 1999).