# MEASURING LIVING STANDARDS WITH PROXY VARIABLES*

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*Very few demographic surveys in developing countries have gathered information on household incomes or consumption expenditures. Researchers interested in living standards therefore have had little alternative but to rely on simple proxy indicators. The properties of these proxies have not been analyzed systematically. We ask what hypotheses can be tested using proxies, and compare these indicators with consumption expenditures per adult, our preferred measure of living standards. We find that the proxies employed in much demographic research are very weak predictors of consumption per adult. Nevertheless, hypothesis tests based on proxies are likely to be powerful enough to warrant consideration.*

Demographic theory has long distinguished the effect of income on behavior from that of education. A household's income summarizes its command over resources, including the resources that could promote health, lessen the need for high fertility, or reduce the opportunity costs of children's schooling. Education is linked closely to income; it is also thought to have a separable and distinctive influence on decision making. Schooling can stimulate the development of cognitive abilities and heighten attention to information (LeVine et al. 1991); it can shift the distribution of authority within the household and equip individuals with the social confidence to claim resources outside the household (Caldwell 1979); and it can impart specific information that is pertinent to demographic decisions (Elo and Preston 1996). The conceptual distinctions between income and education have become a prominent feature of mortality analyses; they figure, for example, in the study of the early-twentieth-century experience in the United States (Preston and Haines 1991) and in much discussion of mortality in developing countries (Cleland and van Ginneken 1988; Stuebing 1997). Similarly, in the economic and sociological theory that supports fertility research, the separate roles of income and education are an important theme (e.g., LeVine et al. 1991; Schultz 1981).

Unfortunately, very few empirical studies of developing countries are able to do justice to this theme: In these countries, demographic surveys seldom gather data on household incomes. The collection of accurate income data is a demanding task; it must compete for survey resources against higher-priority modules on health, mortality, fertility, and children's schooling. Household consumption expenditures are preferred to measures of income on some theoretical grounds, and consumption data are somewhat easier to gather. Nevertheless, the proper measurement of consumption is also a costly undertaking.

In recognition of these difficulties, most demographic surveys have fallen back on a compromise design. The approach has been to collect a disparate set of indicators in the hope that, when taken together, they will somehow serve as good proxies for living standards. The aim of this article is to determine whether the indicators typically collected are, indeed, good proxies.

To evaluate their performance, we require data sets that include both the indicators themselves and the economic variables that they are meant to represent—that is, household consumption expenditures or incomes. The surveys conducted for the World Bank's Living Standards Measurement Study (LSMS) provide this information. We use recent LSMS surveys from five countries that span the major regions and per capita income levels of the developing world: Ghana (1987–1989), Jamaica (1989), Pakistan (1991), Peru (1994), and Tanzania (1993–1994). These surveys are complemented by a 1995 survey from rural Guatemala, the Encuesta Guatemalteca de Salud Familiar (EGSF), which employed a simplified, lower-cost procedure for collecting household consumption data.[1] Of course, six countries do not make a fully general sample, but it is reasonable to suppose that this group encompasses much of the relevant variation.

The plan of the article is as follows. In the first section, we review current research practice in the selection of proxy variables for living standards. Here and throughout the article, we limit attention to demographic studies of developing countries. As will be seen, numerous approaches have been

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1. The LSMS surveys are described in World Bank (1993, 1995a, 1995b, 1996a, 1996b). Tanzania's Human Resources and Development Survey is not, strictly speaking, an LSMS survey, but was conducted with the same protocols. For a summary of the LSMS program and a detailed discussion of the generic LSMS questionnaire, see Grosh and Glewwe (1996). Peterson, Goldman, and Pebley (1997) describe the 1995 Guatemalan survey (EGSF); Gragnolati (1999) evaluates its consumption module.

**TABLE 1. COMPONENTS OF A LIVING STANDARDS INDEX**

| | Ghana 1987–1989 | Guatemala 1995 | Jamaica 1989 | Pakistan 1991 | Peru 1994 | Tanzania 1993–1994 |
|---|---|---|---|---|---|---|
| Access to Clean Water | x | x | x | x | x | x |
| Water on Premises | x | x | x | x | x | x |
| Time to Water < 30 Min. | x | x | x | x | x | x |
| Toilet Facility | x | x | x | x | x | x |
| Flush Toilet | x | x | x | x | x | x |
| Nondirt Flooring | x | x | — | x | x | x |
| Electricity | x | x | x | x | x | x |
| Radio | x | x | x | x | x | x |
| TV | x | x | x | — | x | x |
| Refrigerator | x | x | x | — | x | x |
| Bicycle | x | x | x | x | x | x |
| Motorcycle | x | x | x | x | x | — |
| Car | x | x | x | x | x | — |

explored in the recent literature, and no "best practice" approach has yet emerged. Indeed, one finds surprisingly little discussion of the methodological issues; as a result, the proxy measures seem to have been selected on an ad hoc, study-specific basis.

Our approach is not to examine all of the proxy variable specifications that have appeared in the literature, but rather to give systematic attention to a representative selection. Drawing on the LSMS and EGSF surveys, we assemble a set of about a dozen variables that are commonly used as proxies for living standards. Each of these variables is available in the prototype Demographic and Health Survey (DHS) questionnaire, and each therefore could be considered for inclusion in a demographic analysis. In the remainder of the article, we examine three specifications using these proxy variables.

The necessary statistical context is provided in the second section, where we take up the question of causal modeling with proxy variables. In a causal model, the use of proxies introduces a form of specification error. The consequences are not unlike those of measurement error (Fuller 1987; Griliches 1974), but proxy variables present new and distinct issues. In this section, which draws on MacKinnon (1992), we delineate the theoretical criteria against which such proxies can be judged.

In the third section, we employ these criteria to evaluate the empirical association between the proxy variables and the living standards measure that we take them to represent. The proxies are compared with household consumption expenditures per adult, our preferred measure of living standards. We defend the choice of consumption expenditures and discuss the alternatives. As we show, even the best-performing proxy variables and indices are associated only weakly with consumption per adult. Nevertheless, they can be put to good use in testing one important hypothesis about the influence of living standards.

In the fourth section, we return to the larger theoretical question: What distinctive contribution to demographic behavior is made by education, as compared with the contribution of consumption? To address this question, we present empirical models of three important demographic domains: lifetime fertility, child survival, and children's schooling. We estimate specifications that incorporate consumption per adult, and compare the results with those from alternative specifications based on proxies. The central issue in the comparison is how the use of proxies affects the estimated contribution of mother's education and the statistical significance of consumption expenditures.

In the final section, we set out the main findings of the research, addressing both methodology and the theoretical debate.

## CURRENT RESEARCH PRACTICE

In Appendix Table A1, we present a sample of recent micro-level demographic analyses that employ measures of living standards. The entries refer to articles with a developing-country focus published in either *Demography* or *Population Studies* from 1990 to 1996. The DHS is represented prominently among the data sources, but a number of other surveys also make an appearance. As shown in the last column of the table, only three of the analyses use a measure of income or consumption expenditures as such (Lloyd and Gage-Brandon 1994; Sastry 1996; Stewart et al. 1991). The diversity of alternative specifications is striking: To judge from this list, there seems to be no generally accepted method for constructing an index of living standards from the ingredients available in demographic surveys.

If these specifications possess a common feature, it is the reliance on at least one of three sets of measures: access to water and the nature of toilet facilities, indicators of housing quality, and ownership of selected consumer durables. The LSMS and EGSF surveys contain data on these variables

**TABLE 2. PERCENTAGES OF HOUSEHOLDS WITH INDEX ITEMS**

| | Ghana | Guatemala | Jamaica | Pakistan | Peru | Tanzania |
|---|---|---|---|---|---|---|
| Access to Clean Water | 24.0 | 54.6 | 79.3 | 43.2 | 71.7 | 44.1 |
| Water on Premises | 12.6 | 65.0 | 60.5 | 38.5 | 66.8 | 19.8 |
| Time to Water < 30 Min. | 67.3 | 92.4 | 26.0 | 94.7 | 97.6 | 64.5 |
| Toilet Facility | 72.5 | 16.4 | 97.6 | 67.4 | 60.9 | 95.8 |
| Flush Toilet | 6.0 | 8.3 | 25.2 | 40.7 | 51.5 | 8.4 |
| Nondirt Flooring | 77.7 | 39.9 | — | 51.6 | 60.6 | 50.6 |
| Electricity | 25.4 | 48.8 | 65.3 | 80.1 | 71.5 | 26.3 |
| Radio | 26.0 | 73.4 | 70.0 | 20.3 | 86.9 | 43.1 |
| TV | 7.6 | 33.4 | 51.9 | — | 72.9 | 3.2 |
| Refrigerator | 7.0 | 7.4 | 45.4 | — | 42.2 | 7.7 |
| Bicycle | 12.8 | 33.5 | 12.5 | 36.2 | 24.9 | 1.7 |
| Motorcycle | 0.6 | 2.1 | 2.0 | 10.6 | 3.4 | — |
| Car | 3.0 | 7.9 | 8.2 | 2.9 | 6.8 | — |

comparable to those gathered in the generic DHS survey. Table 1 describes the index elements available in both the LSMS/EGSF and the DHS surveys.[2]

Some researchers might object to the inclusion of electricity-dependent consumer items on the grounds that access to electricity is a community rather than a household characteristic (Knodel and Wongsith 1991). We think it is reasonable to include them, however, given the possibilities afforded by batteries, generators, and electrical line taps. After considering whether to include measures of the spouse's occupation or education, we elected not to include these measures. In several of our sample countries—most notably Ghana, Jamaica, and Peru—marriage dissolution is common, informal unions are important, and spouses need not coreside. These demographic difficulties are not handled consistently in the LSMS surveys, and to restrict the analysis to currently married, spouse-present women would reduce the LSMS sample sizes and might cause sample selection or endogeneity bias.

Table 2 indicates the percentages of households—these are households with at least one woman in the 15–49 age range—possessing the index items for the six sample countries. We will consider three standard of living indices (SLI) formed from these components. The first (SLI-1) is a simple summation of the number of items present. (The maximum differs slightly from one country to the next.) A second measure (SLI-2) is specified with dummy variables for each value of SLI-1; the lowest value (or set of values) is treated as the omitted category. This specification is useful in allowing the sum of the index items to exert a nonlinear influence. The third specification (SLI-3) treats each index item as a distinct indicator, thereby introducing a set of 10 to 12 dummy variables.

## CAUSAL MODELING WITH PROXY VARIABLES

What are the implications of using such proxy indicators in an otherwise well-specified causal model? In this section, we explore the issues with the aid of large-sample statistical theory and Monte Carlo experiments. The theoretical results are presented here without proof, but the interested reader can find the proofs in our companion paper (Montgomery et al. 1999). To bring the key issues to the forefront, we consider the case of linear regression.

Let the correctly specified causal model be given as in Eq. (1):

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\delta + \boldsymbol{\varepsilon}, \tag{1}$$

where we have written the equation in matrix form assuming a sample of $n$ observations. The dependent variable $\mathbf{Y}$ is an indicator of demographic behavior. The covariates $\mathbf{X}$ represent the measured influences on behavior, which would include education. The covariate $\mathbf{Z}$ is the household's standard of living, as expressed in its level of consumption per adult. We assume that $\mathbf{X}$ and $\mathbf{Z}$ are statistically exogenous to the regression disturbance term $\boldsymbol{\varepsilon}$, so that ordinary least squares applied to Eq. (1) would produce consistent estimates of the $\boldsymbol{\beta}$, $\boldsymbol{\delta}$, and $\sigma_\varepsilon^2$ parameters as well as their standard errors.[3]

The causal model of Eq. (1) cannot be estimated as it stands because no data on $\mathbf{Z}$ are available. The researcher,

2. With respect to items related to water and toilet facilities, logical links exist among some index items: For example, "water available on the premises" implies that water is less than 30 minutes away. LSMS surveys generally obtain distance to water sources. We have converted these distance measures to what we think are reasonable time equivalents so as to obtain a variable comparable to that of the DHS.

3. We do not consider here the implications of clustered or multilevel samples, heteroskedasticity, and other statistical complications. For the linear model, an extension of the large-sample results to these cases is straightforward. The exogeneity assumption is addressed in Montgomery et al. (1999). This assumption would be violated if either $\mathbf{X}$ or $\mathbf{Z}$ were measured with error; below, and in greater detail in the companion paper, we consider the implications of such errors.

however, has access to a proxy variable **P**, or to a set of $l > 1$ such proxies, that could be inserted in the equation in place of the unmeasured **Z** variable. (In the cases that we examine, **P** will be represented by one of the SLI indices.) Like **Z**, the proxies **P** are assumed exogenous to $\boldsymbol{\varepsilon}$. What would be gained by the substitution of **P** for **Z**?

## Large-Sample Biases

In a situation such as this, misspecification of the causal model is all but inevitable. To ignore the proxies **P** would bring about one form of specification error, but an analogous form of error would be risked by including them. If the proxies are excluded and Eq. (2) is estimated,

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{u}, \tag{2}$$

with $\mathbf{u} = \mathbf{Z}\delta + \boldsymbol{\varepsilon}$, the estimated coefficient $\hat{\boldsymbol{\beta}}$ will diverge from the causal parameter $\boldsymbol{\beta}$ unless **X** and **Z** happen to be orthogonal.[4] If the proxies **P** are included, we have, instead, Eq. (3):

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{P}\boldsymbol{d} + \mathbf{v}, \tag{3}$$

with $\mathbf{v} = \mathbf{Z}\delta - \mathbf{P}\boldsymbol{d} + \boldsymbol{\varepsilon}$. Once again, $\hat{\boldsymbol{\beta}}$ estimated from this equation will diverge from the true $\boldsymbol{\beta}$ parameter. Furthermore, the $\hat{\boldsymbol{d}}$ coefficients on the proxies **P** will not converge to quantities that shed light on the true $\delta$ parameter, at least in the general case.

We suspect that when faced with such a dilemma, most researchers would follow intuition and include the proxies. Surely, most would reason, it must be better to control for consumption **Z**, however imperfectly, than to omit all measures of it. The proxies **P** presumably contain some information about **Z**, and one might hope at least to reduce the inconsistency of $\hat{\boldsymbol{\beta}}$ by incorporating **P** into the model.

This line of thinking is appealing and can be shown to be correct in special cases (Aigner 1974; Bollen 1989; Maddala 1977; Montgomery et al. 1999; Wickens 1972). Surprisingly, however, it is not correct in general. Proxy controls for **Z** have the potential to reduce inconsistency in $\hat{\boldsymbol{\beta}}$, but such reduction cannot be guaranteed even in very large samples.

## Testing Hypotheses About Consumption

When estimators are inconsistent, as $\hat{\boldsymbol{d}}$ is for $\delta$, hypothesis tests are usually invalid. For a certain kind of hypothesis, however, one can formulate a perfectly valid test by making use of the proxy variables. We refer to a test for $\delta = 0$: that is, a test focused on the relevance of consumption. The test itself is no more than an ordinary chi-square test applied to $\hat{\boldsymbol{d}}$, the proxy variable coefficients, with degrees of freedom equal to $l$, the number of such proxy variables. (Another label for the chi-square test is the Wald test. An $F$ test would be equivalent to the chi-square test in large samples.) Although one might hope to know more about the role of consumption than whether its coefficient is zero, even such partial information would contribute to the demographic debates.

At first glance, this result about testing might be thought curious and even disconcerting. The chi-square test statistic is calculated from $\hat{\boldsymbol{d}}$ and from data on **Y**, **X**, and the **P** proxies. Because the consumption variable **Z** is missing, it cannot itself enter the calculation. Yet the quality of the test must depend somehow on the nature of the relationship between **Z** and its proxies.

Consider an extreme case in which the proxies **P** are utterly uninformative about consumption. If **P** contains no information on **Z**, then a test statistic based on **P** cannot provide a meaningful assessment of the null hypothesis. A meaningful test for $\delta = 0$ should reject the null with high probability when the null is false, and the likelihood of rejection should increase with the difference between the true $\delta$ and the $\delta = 0$ value specified by the null. As the case of uninformative proxies suggests, the strength of the relationship between **Z** and **P** must be manifested in the *power* of the testing procedure.

When the null is false ($\delta \neq 0$), the chi-square test statistic is distributed not as a central chi-square, but as a random variable proportional to a noncentral chi-square. Let $\lambda$ denote the noncentrality parameter. If other things are held constant, the greater is $\lambda$, the greater is the power of the test and the more effective the test will be in diagnosing departures from the null. As shown in MacKinnon (1992) and in our companion paper, one can partition $\lambda$ into four factors:

$$\lambda = R^2 \cdot \left(\frac{\delta}{\sigma_\varepsilon}\right) \cdot \tilde{\sigma}^2_{\mathbf{Z}|\mathbf{X}} \cdot n, \tag{4}$$

in which $\tilde{\sigma}^2_{\mathbf{Z}|\mathbf{X}} = (1/n)\mathbf{Z}'\mathbf{M_X Z}$ and $\mathbf{M_X} = \mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'$. The appropriate measure of association between consumption **Z** and the **P** proxies is the first factor shown above, which is a partial $R^2$. This is the $R^2$ taken from a two-step regression, in which **Z** and **P** are each regressed on **X**, and the residual $\mathbf{e_Z}$ is then regressed on the set of residuals $\mathbf{e_P}$. The $R^2$ from the second step reveals the degree to which the proxies **P** explain **Z** net of the **X** covariates.

In addition to the partial $R^2$, a factor that comes into play only when proxy variables are employed, three other factors determine $\lambda$ and, through it, the power of the chi-square test. These are, respectively, the size of the $\delta$ coefficient relative to the standard error $\sigma_\varepsilon$, the empirical variability of consumption **Z** net of other covariates **X**, which we have denoted by $\tilde{\sigma}^2_{\mathbf{Z}|\mathbf{X}}$, and $n$, the sample size. These three factors would determine $\lambda$ even if **Z** were actually available; as shown in Montgomery et al. (1999), they continue to exert influence when **Z** is missing.

To sum up, for the narrow purpose of testing the hypothesis $\delta = 0$, it makes good sense to use proxy variables provided that they are arguably highly correlated, net of **X**, with the unobserved consumption variable. The test will have lower power than if **Z** itself were available, and the partial $R^2$ summarizes concisely the loss of information.

4. By *diverge* we mean that $\hat{\boldsymbol{\beta}}$ is inconsistent for $\boldsymbol{\beta}$, the parameter of the causal model specified in Eq. (1). For definitions of terms and more precise statements of conditions and conclusions, see Montgomery et al. (1999). The orthogonality of **X** and **Z** does not imply that the standard errors of $\hat{\boldsymbol{\beta}}$ will be estimated consistently.

## A Monte Carlo Illustration

An example may help to clarify these points. Consider the simple linear model $\mathbf{Y} = \mathbf{Z}\delta + \boldsymbol{\varepsilon}$, in which $\mathbf{Z}$ is the single explanatory variate and both $\mathbf{Z}$ and $\boldsymbol{\varepsilon}$ are standard normal. Suppose that a single proxy variable $\mathbf{P}$ is available; it is also standard normal but is correlated with $\mathbf{Z}$, with $\rho$ being the correlation coefficient. Because there are no $\mathbf{X}$ variables in the model, the partial $R^2$ value is simply $\rho^2$, the square of the raw correlation coefficient.

One can show that the regression coefficient $\hat{d}$, which is drawn from the misspecified regression $\mathbf{Y} = \mathbf{P}d + \mathbf{v}$, converges not to $\delta$, but rather to $\rho\delta$ as sample size grows. The regression-based variance estimator $s^2$, which should converge to $\sigma_\varepsilon^2 = 1$, converges instead to $\delta^2(1-\rho^2) + 1$. Whereas $\hat{d}$ is a downwardly biased estimator of $\delta$, the estimator $s^2$ is upwardly biased for $\sigma_\varepsilon^2$.

In spite of these biases, the proxy variables estimator $\hat{d}$ can be effective in testing the null hypothesis. To illustrate this, we present the results of a Monte Carlo experiment. Figure 1 depicts the probability of rejecting the null $\delta = 0$ for a range of values of $\delta$ and sample sizes.[5]

As would be expected, the probability of rejecting $\delta = 0$ increases with the true $\delta$ value for all sample sizes. (As shown in Eq. (4), it is actually the changing ratio of $\delta$ to $\sigma_\varepsilon$ that generates the upward slope of these curves; here, we assume $\sigma_\varepsilon = 1$.) With the true value of $\delta$ held constant, the probability of rejection increases with the sample size. For sample sizes in the range typically seen in demographic applications ($n > 500$), the probability of rejecting the null is reasonably high; the likelihood exceeds 0.7 where the value of $\delta$ exceeds one-half. Of course, the actual value of $\delta$ is unknown. As the figure shows, it is much harder to discriminate between the zero value for $\delta$ specified in the null hypothesis and nonzero but small values of the $\delta$ parameter. Even in the largest samples considered here, the null is rejected less than 25% of the time for true values of $\delta$ that are less than one-tenth of $\sigma_\varepsilon$. In short, if consumption is thought to affect behavior, but one expects the effect to be relatively small, then the chi-square test will be unlikely to reject the hypothesis of no effect whatever.

As we emphasized above, these rejection probabilities depend on the value of the partial $R^2$ between $\mathbf{Z}$ and the proxy $\mathbf{P}$, which is equal to $\rho^2$ in this instance. Figure 2 shows how the likelihood of rejection varies with $\rho$ for a sample size of 1,000 observations. If the correlation between $\mathbf{P}$ and $\mathbf{Z}$ is fairly high (the $\rho = 0.50$ case), so is the probability of rejecting the null. Weaker correlations are associated with decidedly lower probabilities of rejection; in the extreme (represented here by $\rho = 0.01$), the null is rejected 5% of the time whatever the true $\delta$ value. In such extreme cases, the outcome of the test provides no diagnostic information. Because $\hat{d}$ converges to $\rho\delta$ rather than to $\delta$, this estimator is also a misleading guide to the true value of $\delta$.

As we have seen in this example, failure to reject can reflect no more than the inadequacies of the proxy variables. To know what message the chi-square test is likely to convey, we clearly must have some prior knowledge of the correlation between $\mathbf{Z}$ and these proxies.

## Revisiting the Assumptions

The theoretical results discussed above were secured with a minimum of assumptions about the relationship between $\mathbf{Z}$ and the proxy variables. In particular, the results have not required an auxiliary model that explicitly links $\mathbf{Z}$ to the $\mathbf{P}$ proxies. No statistical method is free of assumptions, however; here we draw attention to the two key assumptions that underlie our approach.

**Dual roles.** The first of these is an assumption that separates the proxy variables $\mathbf{P}$ from the other $\mathbf{X}$ covariates that are included in the model. The distinguishing feature of a proxy variable is that, according to the theory that informs the causal model, it does not directly enter the model. Its role is simply to stand in for $\mathbf{Z}$, the missing variable that belongs in the causal specification. If $\mathbf{Z}$ were available, the proxies $\mathbf{P}$ would have no role to play; $\mathbf{P}$ therefore would be excluded from the causal model. Because such exclusion restrictions are justified mainly by theory, the distinction between the $\mathbf{X}$ and $\mathbf{P}$ variables will inevitably be controversial, a matter on which different researchers, equipped with different theories, might well disagree.

Returning to the measures listed in Table 1, we note that several could play dual roles: They could be proxy measures for consumption and, at the same time, could exert their own direct causal influences on behavior. The access to water measures, for instance, could exert an important causal influence on child mortality. In a mortality analysis, such variables would be properly treated as belonging to the set of $\mathbf{X}$ covariates. In an analysis of children's schooling or fertility, however, theory might suggest that the water measures have no direct influence. Depending on the context, then, a given variable might be assigned to either the $\mathbf{P}$ or the $\mathbf{X}$ category.

When the data include the consumption variable $\mathbf{Z}$, the researcher will have some freedom to test for the direct causal contribution of other variables. When $\mathbf{Z}$ is missing, however, it becomes much more difficult to determine whether to place a variable in the $\mathbf{P}$ or the $\mathbf{X}$ category. Transferring a variable to the $\mathbf{X}$ category entails a cost: As the number of variables in $\mathbf{P}$ is reduced, so is the number of degrees of freedom for the chi-square test. In some circumstances, this situation could weaken the power of the test.[6]

Rather than framing the issues in terms of proxy variables and their association with a potentially observable $\mathbf{Z}$, as we have done, one can take an entirely different approach. The living standards measure $\mathbf{Z}$ can be conceptualized as an

5. We apply the conventional 5% rejection criterion and assume a value of $\rho = 0.25$ for these simulations. The points shown in the figure are the average values of 5,000 replications. The figure is symmetric about zero, and attention therefore can be restricted to nonnegative $\delta$ values.

6. Because transferring a variable from the $\mathbf{P}$ to the $\mathbf{X}$ category also affects the partial $R^2$ and $\tilde{\sigma}^2_{\mathbf{Z}|\mathbf{X}}$, the net effect of the transfer on test power is unclear.

**FIGURE 1. PROBABILITY OF REJECTING THE NULL δ = 0, GIVEN ρ = 0.25**

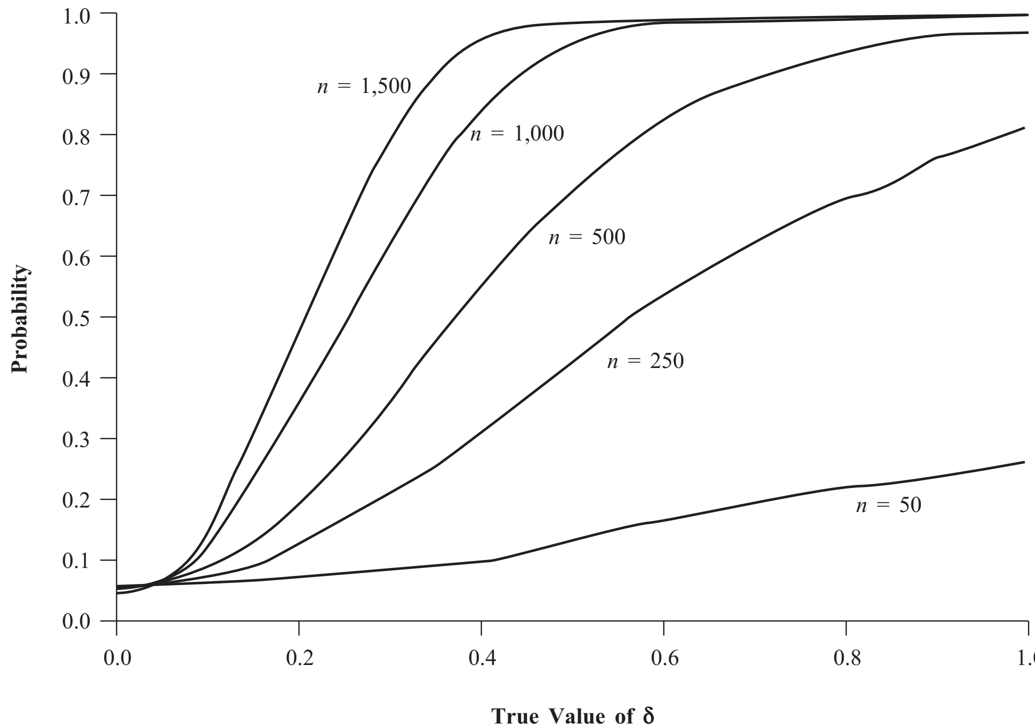
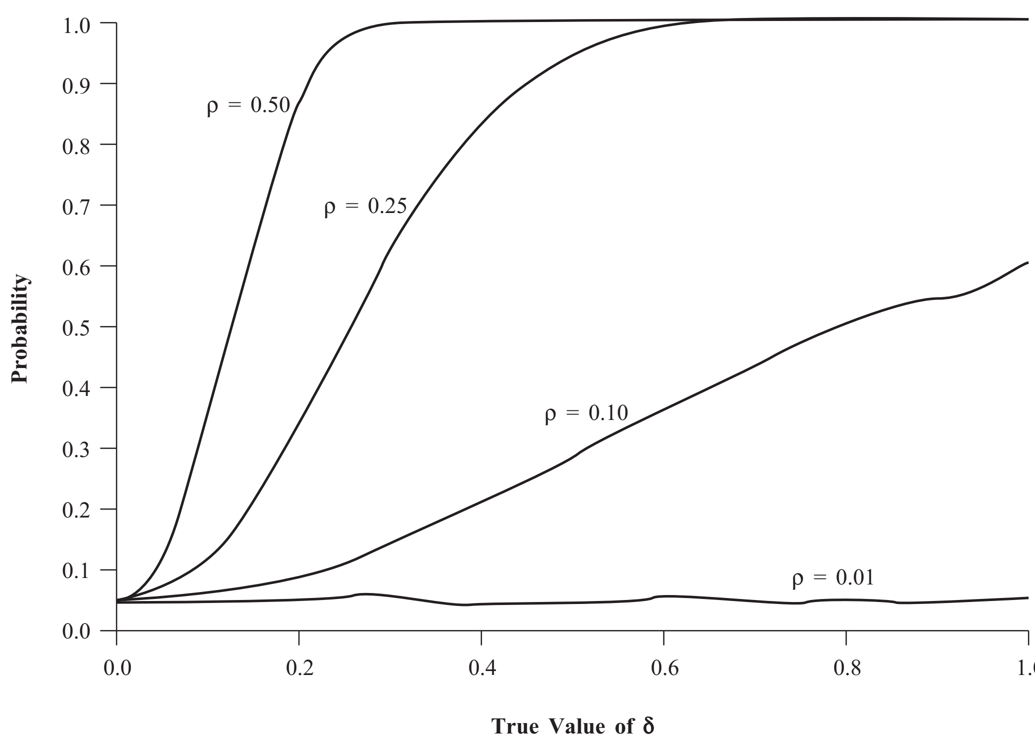



**FIGURE 2. PROBABILITY OF REJECTING THE NULL δ = 0, FOR SAMPLE SIZE *n* = 1,000**



inherently unobservable latent construct. One then can use factor analysis, multiple-indicator methods, or related techniques to model the links between the unobserved **Z** and the observed **P** indicators. Bollen and Lennox (1991) provide an instructive review of such methods. The potential benefit is that, in some cases, the researcher can use both the **X** and **P** variables to model the latent **Z** construct.

Such alternative approaches have their own costs. First, they require the researcher to make explicit assumptions about the auxiliary model in which the relationship between **Z** and **P** is spelled out. The auxiliary model contains unknown parameters and a set of disturbance terms whose statistical distributions must be specified. (The proxy indicators used in demographic applications are generally discrete-valued.) Theory can rarely supply a justification for these assumptions, and they are not easily tested by statistical means. Second, the researcher's concept of living standards may well require more than one latent construct.[7] Third, when **Z** is assumed to be inherently unobservable, researchers are severely restricted in their ability to assess the power of hypothesis tests and to scrutinize other aspects of model specification.

**Exogeneity.** All of the approaches that we have described are vulnerable to errors of measurement and to statistical endogeneities that induce an association between the disturbance term $\boldsymbol{\varepsilon}$ of the causal model and **P** or **Z**. In an effort to learn more about the partial $R^2$ between **Z** and **P**, we assert that **Z** is equivalent to consumption expenditures per adult. This assertion carries some risk. Because consumption expenditures are important to much economic theory—as we discuss below—the problem of measurement error in consumption is the subject of active research (see, for example, Grosh, Zhao, and Jeancard 1995; Hentschel and Lanjouw 1996; Montgomery et al. 1999). Although the literature has yet to produce a consensus on the size and nature of such errors, the potential for bias is well recognized. A skeptic might argue that consumption expenditure per adult is itself no more than a proxy for **Z**. If this is so, then the analyses above could easily be reinterpreted with consumption in a proxy role; but other means would have to be found to estimate its partial $R^2$ with the true **Z**.

Where the proxy variables **P** are concerned, the issue is less that of measurement error than of statistical endogeneity. The proxies reflect household decisions about purchases of durables and, less directly, choices about migration and household location. Such endogenous proxies may be affected by unmeasured household traits that also happen to be embedded in the $\boldsymbol{\varepsilon}$ disturbance term of the causal model. If the **P** indicators are associated in this way with $\boldsymbol{\varepsilon}$, then neither the latent-variables nor the proxy-variables methods can be rigorously justified. The statistical consequences of measurement error in **Z** and of endogeneity in **P** are much the same.

7. In a recent article, Filmer and Pritchett (1999) advocated the use of principal components analysis, in which the first principal component derived from the set of proxy measures **P** is taken to represent the household's unobserved standard of living. To determine the statistical properties of their method, one would have to decide how to treat the other principal components and how to characterize the disturbance term of the auxiliary model.

In summary, a good deal remains to be learned before any one approach can be anointed with the title "best practice." The properties of latent variables methods must be better understood, and the assumptions of this approach must be carefully compared with those of the proxy variables method we favor. Both approaches must be assessed in light of errors of measurement and the possibilities of statistical endogeneity. In our judgment, when we take into account how little the issues have yet been analyzed, the research agenda is most effectively advanced by an initial focus on the proxy variables approach. This approach at least has the merit of placing an observable counterpart to **Z**, consumption expenditures per adult, under close scrutiny.

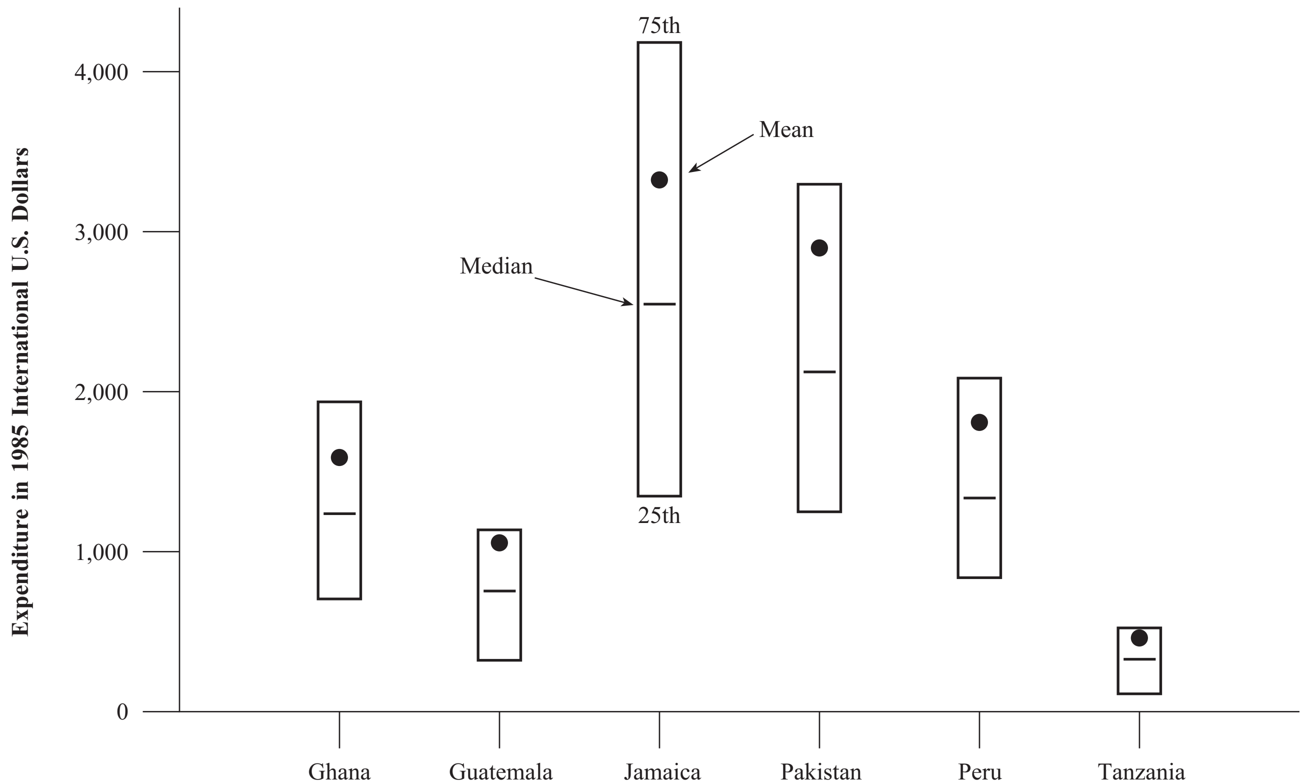
## THE STANDARD OF LIVING INDICES AND CONSUMPTION

What aspects of theory and measurement support the use of consumption expenditures? In poor countries, no single empirical measure can be expected to display all the facets of the concept of long-term income. We believe that consumption per adult is the most appropriate measure of the concept among the measures that are collected in cross-sectional surveys. Nevertheless, we should not proceed without commenting on its potential weaknesses and the empirical alternatives. The main lines of the argument are given below; a more detailed discussion is available in the companion paper.

Why not use measured incomes as such? The reason is that in developing countries, households often draw their incomes from multiple sources that can change from year to year and even from season to season. To properly measure income for a single year requires attention to the details of primary and secondary employment and to the nature of payment for each adult household member. Transfers and income derived from other sources also must be measured, as must the costs (borne in family farms or businesses) of generating income. The transitory nature of some employment, coupled with the uncertainty of net economic return, makes it implausible to regard any one year's income as representative of the incomes earned over the longer time span in which demographic decisions are made.

Most households have access to means of transferring resources across time periods, and save and borrow through a variety of mechanisms that partly shield their consumption levels from the variabilities of income. When it is possible to borrow and save without incurring heavy transactions costs, one can view income as having both transitory and permanent components, with consumption being closely related to the permanent component. The notion of frictionless borrowing and saving is, of course, something of a fiction in poor countries. Even where such possibilities are limited, however, consumption should be a "smoothed" version of a highly variable income stream and should better represent the conceptual ideal than would income as such. One could edge even closer to the conceptual ideal by gathering longitudinal data on incomes, but this is not feasible in a cross-sectional survey.

FIGURE 3. EXPENDITURE PER ADULT BY COUNTRY: 1985 INTERNATIONAL U.S. DOLLARS




Properly designed surveys will measure the implicit value of consumption activities that do not pass through the market. For instance, the LSMS program has a well-developed protocol for assigning monetary value to farm goods that are produced and consumed by farm households; these values are added to the total of consumption expenditures for the household. Also, the "services" implicitly provided by consumer durables are calculated and added to the total; these calculations use the dates of purchase of the durables, estimates of current value, and assumptions about depreciation. Hence, many of the consumer durables listed in the standard-of-living indices shown above (see Table 1) are already included in total consumption expenditures.

Why should total consumption expenditures, calculated in this way, then be divided by the number of adults in the household? The intention is to capture the command over resources wielded by the adults who make demographic decisions. Although an average for consumption is conceptually inferior to a measure of each adult's individual consumption, these data are not easily linked to particular household members. In demographic applications, one must avoid using total household size, rather than the number of adults, as the denominator. Such per capita measures would logically confound an explanatory variable (consumption per capita) with a component of the dependent variable (fertility, mortality). As shown by Casterline (1988) and Casterline, Cooksey, and Ismail (1989) in penetrating analyses of Egyptian mortality, the per capita specifications can produce seriously misleading results.

## Empirical Associations

We now come to the central question: Do the SLI measures described above serve as reliable proxies for consumption expenditure per adult? Figure 3 shows box plots of consumption per adult in the six study countries.[8] As can be seen, the sample countries vary considerably in the level and dispersion of consumption per adult. The line in the middle of each

8. In generating this figure, we have adjusted for within-country price variation where possible. We have also converted all local currency amounts to their equivalents in international U.S. dollars in the survey year. The conversion involves the use of indices of purchasing power parity (PPP) taken from the most recent Penn World Tables of version Mark 5.6, an update of the data described in Summers and Heston (1991). For Tanzania, no recent estimate of PPP is available, and we have used exchange rates to convert the Tanzanian shilling to dollars; this procedure underestimates the standard of living. For Peru, the most recent PPP measure available in the Penn World Tables is for 1992; given the extent of macroeconomic turmoil from 1992 to 1994, the Peruvian estimates also may be artificially low. These conversion difficulties affect Figure 3 and distort cross-country comparisons, but do no harm to our within-country analyses. The conversions simply scale the expenditure variables.

box represents the median value; above it is the mean. The lower and upper borders of each box indicate the 25th and 75th percentiles of the distributions. Tanzania is the poorest country in this sample; indeed, it is among the poorest countries in the world. Ghana, by comparison at least, is much better off, and in our sample Jamaica exhibits the highest consumption levels. There is considerable overlap across countries in these distributions, with the poorer Jamaicans roughly on par with the richer Ghanaians.

Figures 4 and 5 display the distribution of consumption per adult by country, according to the number of items in the SLI. Box-and-whisker plots depict the central tendencies and ranges. Although some irregularities are apparent in these figures, they show that the SLIs contain information about the level of consumption per adult. The median values of consumption tend to increase with the number of items in the index, as do the 25th and 75th percentiles, apart from a few exceptions. Similar figures (not shown) are produced

FIGURE 4. CONSUMPTION EXPENDITURES PER ADULT AND THE STANDARD OF LIVING INDEX: GHANA, GUATEMALA, PAKISTAN, AND TANZANIA

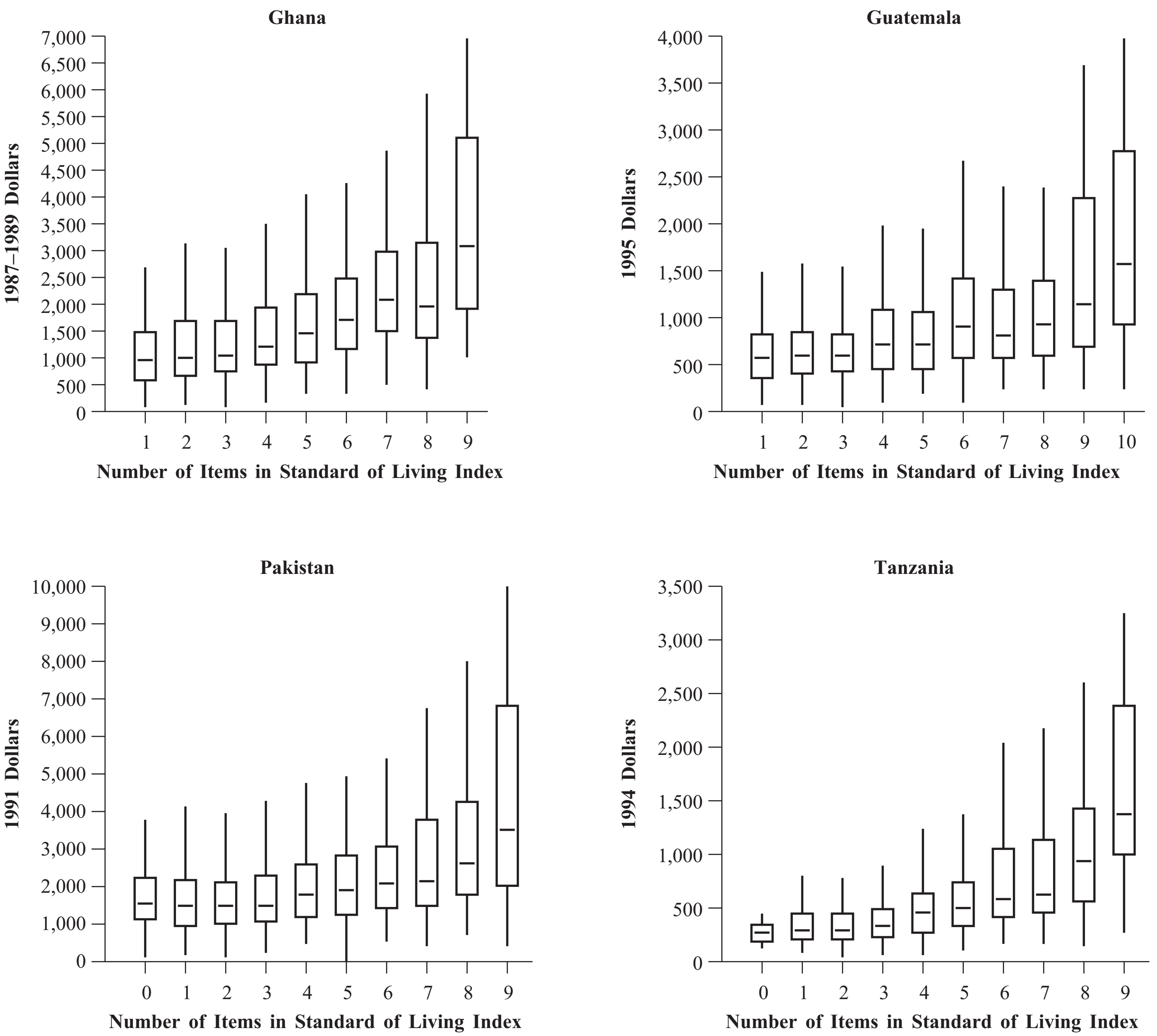
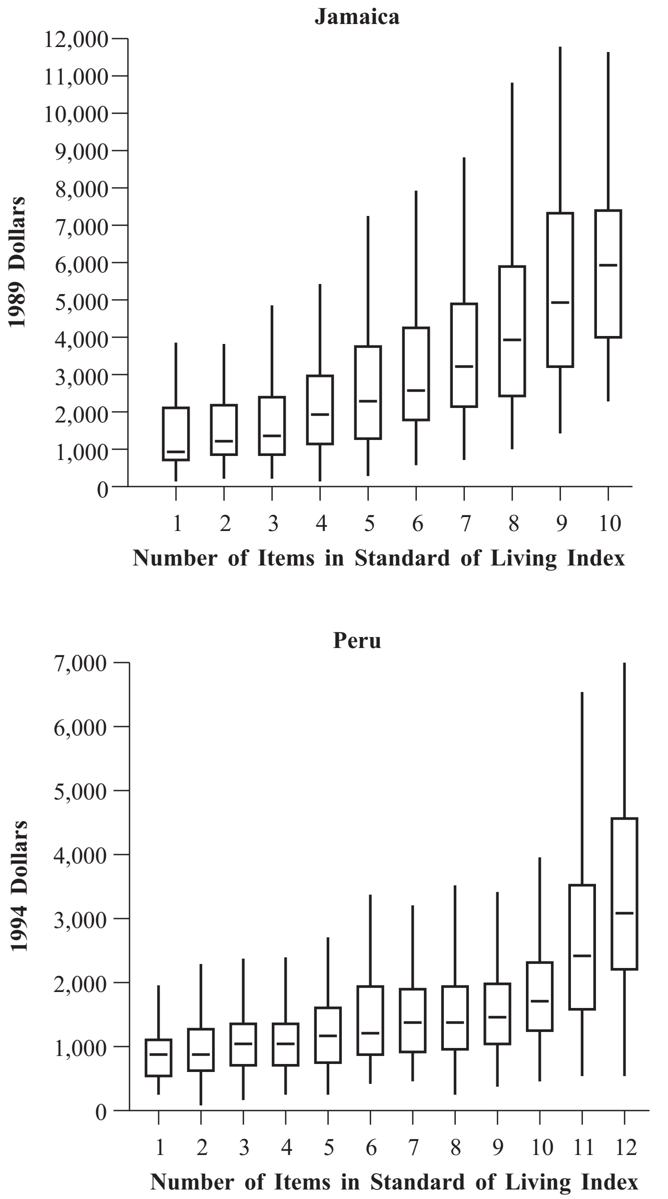


**FIGURE 5. CONSUMPTION EXPENDITURES PER ADULT AND THE STANDARD OF LIVING INDEX: JAMAICA AND PERU**




when we plot separately the relationships for urban and rural areas within each country. As a rule, the urban consumption levels are higher than the rural at each value of the SLI, but in both urban and rural areas, the index is associated positively with consumption.

These central tendencies are encouraging, but to judge the quality of the SLI proxies, we need to know the partial $R^2$ values, which measure the strength of the association between consumption per adult and the SLI proxies with the joint effects of other covariates removed. The empirical variability of consumption **Z** net of other **X** covariates, a factor that we have denoted by $\tilde{\sigma}^2_{Z|X}$, is also an important consideration. So, too, is the sample size.

Table 3 presents the key items of information. To provide context, the top portion displays the ordinary $R^2$ values taken from a regression of consumption expenditures per adult on the various SLI measures. We show the $R^2$ values for the full samples and separately for the urban and rural subsamples of each country. These "raw" $R^2$ values are alarmingly low. They indicate that although the proxy indices contain some information about consumption, they do not contain very much information. Of the three indices, the one with the greatest explanatory power is SLI-3, the dummy variable specification with dummy variables for each of the specific index items.

The picture is not improved when we consider the theoretically appropriate partial $R^2$ values shown in the second portion of the table. (The other covariates employed include the woman's education, her age and powers of age, and a set of dummy variables for regions. We discuss these covariates below.) Here, the $R^2$ values drop as low as .015 (for Pakistan); even at their best, they attain a level of only .150 (for Jamaica). If taken by themselves, these partial $R^2$s would indicate that proxy-based tests for the relevance of consumption might have distressingly low power.

Fortunately, the power of the chi-square test is not decided by the partial $R^2$ values alone. It also depends on the variability of consumption expenditures per adult. This is the factor denoted by $\tilde{\sigma}^2_{Z|X}$, shown in the bottom portion of Table 3. We see that consumption is highly variable net of other covariates; such variation will enhance the test's ability to detect departures from the null hypothesis.[9] Test power is further enhanced by large sample sizes. To roughly gauge the power of the chi-square test, one can multiply the partial $R^2$ value by both $\tilde{\sigma}^2_{Z|X}$ and the sample size. If the product exceeds 20 (see Montgomery et al. 1999), then one can reasonably expect the chi-square test statistic to have acceptable power.[10] Even in Tanzania, which has the lowest value of $\tilde{\sigma}^2_{Z|X}$ as shown in Table 3, this conclusion will hold for samples of the size normally used by demographers.

In summary, the message delivered by Table 3 is ultimately reassuring. Although the SLI proxies are extremely weak when judged by their partial $R^2$ values, demographic sample sizes are usually large enough, and consumption per

9. Here and in the discussion that follows, the expenditure data are scaled by 100.

10. Two issues need further consideration. First, the ratio of the true coefficient on expenditures $\delta$ to $\sigma_\varepsilon$ will affect the power of the test. When $\delta$ is expected to be very small in relation to $\sigma_\varepsilon$, this will imply a need for larger samples and a highly variable consumption measure if test power is to reach acceptable levels. Second, because the chi-square test statistic is based on $s^2$ rather than on the true $\sigma^2_\varepsilon$, it will not be distributed as noncentral chi-square but rather as a random variable that is proportional to such a noncentral chi-square variate (see Montgomery et al. 1999). The factor of proportionality is less than unity; as a result, the test statistic is smaller than the noncentral chi-square variate, and the likelihood of rejecting the null hypothesis is reduced further.

**TABLE 3. REGRESSIONS OF EXPENDITURE PER ADULT ON STANDARD OF LIVING INDICES**

| | Ghana | Guatemala | Jamaica | Pakistan | Peru | Tanzania |
|---|---|---|---|---|---|---|
| $R^2$ Values | | | | | | |
| SLI-1 | | | | | | |
| Full sample | .104 | .077 | .143 | .030 | .154 | .155 |
| Rural | .014 | | .106 | .025 | .132 | .017 |
| Urban | .082 | | .094 | .036 | .108 | .114 |
| SLI-2 | | | | | | |
| Full sample | .129 | .103 | .154 | .033 | .220 | .185 |
| Rural | .020 | | .135 | .033 | .163 | .031 |
| Urban | .123 | | .101 | .038 | .180 | .140 |
| SLI-3 | | | | | | |
| Full sample | .156 | .178 | .224 | .077 | .226 | .215 |
| Rural, urban | .041 | | .177 | .047 | .192 | .079 |
| Urban | .136 | | .192 | .141 | .184 | .170 |
| Partial $R^2$ Values Net of Other Covariates | | | | | | |
| SLI-1 | .030 | .047 | .078 | .015 | .063 | .072 |
| SLI-2 | .064 | .064 | .090 | .017 | .124 | .109 |
| SLI-3 | .072 | .136 | .150 | .053 | .130 | .137 |
| $\tilde{\sigma}^2_{Z\|X}$ Values | 131.4 | 162.2 | 811.8 | 1,323.7 | 191.7 | 38.8 |

adult would seem to be variable enough, to make tests based on the SLI proxies worth considering. The chi-square test can be expected to reject the null hypothesis—that consumption does not matter—with reasonably high probability when that null is false. To be sure, the test is less powerful than a test based on consumption itself (this is the consequence of the low partial $R^2$ values), and certainly one would not want to further consider the SLI specifications with the lower partial $R^2$s. In the discussion that follows, then, we retain the SLI-3 measure, which is the best-performing measure of a poorly performing group, and assess its role in models of fertility, child mortality, and children's schooling.

## FERTILITY, CHILD MORTALITY, AND CHILDREN'S SCHOOLING

Here we compare estimates based on consumption expenditures per adult with alternatives based on SLI-3. For the fertility models, we specify a base set of explanatory variables; these include a woman's education, her age, age squared and age cubed, urban residence, and as detailed a set of regional indices as are available in the LSMS/EGSF data. The approach is generally similar for child mortality and schooling, although in these models the base set includes measures of the child's birth order and birth year, and the mother's age at birth. We then add to this base set the consumption per adult variable, and test its significance. In the alternative specification, we add the SLI-3 dummy variables and test for their joint statistical significance, using the chi-square test.

In preliminary analyses (not shown here), we found that the effects of per adult expenditure were systematically different in rural and urban areas.[11] The expenditure variables therefore are entered directly and as an interaction with an urban dummy variable. To accomplish this in the SLI specifications, we have interacted the total number of SLI items (SLI-1) with an urban dummy variable.

We estimate the cumulative fertility models using the ordered-probit technique (Greene 1997) with children ever born as the dependent variable. We include all women of reproductive age (15–49) in the analyses. As for child mortality, the surveys in three countries—Ghana, Guatemala, and Pakistan—include birth history data for the woman that allow mortality risks to be modeled child by child. We use Cox proportional hazards models for these analyses. The same three countries provide child-by-child information on the years of schooling completed by the woman's children, which we model using the ordered-probit method.

Table 4 presents the sample means for selected covariates. Here and in the discussion that follows, we limit attention to the measures of consumption expenditures and women's education, because the contrast between their ef-

11. The definition of *urban* differs across countries. In Jamaica, for example, the urban areas are the Kingston Metropolitan Area and "other towns." In Peru an urban area is one with at least 2,000 inhabitants.

**TABLE 4. SELECTED SAMPLE MEANS**

| | Ghana | Guatemala | Jamaica | Pakistan | Peru | Tanzania |
|---|---|---|---|---|---|---|
| Samples of Women | | | | | | |
| Children ever born | 3.24 | 2.71 | 2.06 | 3.16 | 2.22 | 2.87 |
| Woman's age | 28.46 | 25.50 | 27.13 | 27.81 | 29.04 | 27.45 |
| Urban | .350 | | .484 | .509 | .679 | .684 |
| Schooling | | | | | | |
| Primary | .132 | .587 | | .104 | | |
| Middle | .206 | | | .058 | | .110 |
| Secondary | .167 | .091 | .687 | .163 | .438 | |
| Postsecondary | | | .143 | | .194 | |
| Samples of Children | | | | | | |
| Child mortality ($_5q_0$) | .170 | .087 | | .164 | | |
| Mean years of schooling | 3.57 | 1.37 | | 2.64 | | |

fects is perhaps of greatest theoretical interest. The structure of education varies considerably across the study countries. In each case, we have used the lowest category as the omitted category, but in Ghana, for example, this is no schooling, whereas in Jamaica, it is less than secondary schooling.

## Fertility

In Table 5, the ordered-probit estimates of fertility are summarized; the main results are as follows. In rural areas, expenditure per adult is either insignificant or associated posi-

**TABLE 5. MODELS OF CHILDREN EVER BORN: SELECTED ORDERED-PROBIT COEFFICIENTS**

| | Ghana | Guatemala | Jamaica | Pakistan | Peru | Tanzania |
|---|---|---|---|---|---|---|
| Number of Women | 4,291 | 2,816 | 2,153 | 5,193 | 4,558 | 6,742 |
| Expenditure per Adult Coefficients | | | | | | |
| Expenditure per adult (00's) | $.040 \times 10^{-1}$ | $.063 \times 10^{-1}$ | $-.002 \times 10^{-1}$ | $.014 \times 10^{-1}$ | $.055 \times 10^{-1}$ | $.033 \times 10^{-1}$ |
| | (1.85) | (3.94) | (0.18) | (2.94) | (1.80) | (3.96) |
| Expenditure × urban | $-.087 \times 10^{-1}$ | | $-.033 \times 10^{-1}$ | $-.023 \times 10^{-1}$ | $-.026 \times 10^{-1}$ | $-.035 \times 10^{-1}$ |
| | (3.11) | | (2.08) | (2.84) | (0.79) | (4.10) |
| Urban | –.242 | | –.018 | .122 | –.211 | –.225 |
| | (4.18) | | (0.25) | (3.23) | (3.32) | (5.17) |
| Chi-Square Tests on Expenditure Coefficients: *p* Values | | | | | | |
| Both equal zero | .006 | .000 | .008 | .005 | .020 | .000 |
| Urban equals zero | .010 | | .002 | .167 | .027 | .316 |
| Women's Education Coefficients | | | | | | |
| Primary school | .097 | –.322 | | –.252 | | –.139 |
| | (1.95) | (7.13) | | (4.88) | | (3.96) |
| Middle school | .007 | | | –.359 | | |
| | (0.16) | | | (4.71) | | |
| Secondary school | –.061 | –1.018 | –.137 | –.702 | –.619 | –.850 |
| | (1.31) | (11.80) | (2.07) | (11.56) | (14.27) | (14.07) |
| Postsecondary school | | | –.659 | | –1.418 | |
| | | | (7.40) | | (24.26) | |
| Chi-Square Tests on Education Coefficients: *p* Values | | | | | | |
| All equal zero | .070 | .000 | .000 | .000 | .000 | .000 |

*Note:* $|Z|$ statistics are shown in parentheses.

**TABLE 6. COMPARISON OF FERTILITY MODELS USING PROXIES AND EXPENDITURES**

| | Ghana | Guatemala | Jamaica | Pakistan | Peru | Tanzania |
|---|---|---|---|---|---|---|
| Chi-Square Tests on Proxies: *p* Values | | | | | | |
| All equal zero | .000 | .000 | .000 | .011 | .000 | .000 |
| Women's Education Coefficients Based on Proxies | | | | | | |
| Primary school | .081 | –.251 | | –.285 | | –.111 |
| Within confidence band around Table 5 estimate | yes | yes | | yes | | yes |
| Middle school | .010 | | | –.353 | | |
| Within confidence band | yes | | | yes | | |
| Secondary school | –.037 | –.751 | –.126 | –.685 | –.493 | –.576 |
| Within confidence band | yes | no | yes | yes | no | no |
| Postsecondary school | | | –.562 | | –1.193 | |
| Within confidence band | | | yes | | no | |
| Chi-Square Tests on Education Coefficients: *p* Values | | | | | | |
| All equal zero | .253 | .000 | .000 | .000 | .000 | .000 |

tively with fertility. By contrast, in urban areas (where one must add the two expenditure coefficients to see the effect), higher expenditures generally either reduce fertility or have no net effect, except for Peru. One can see the significance of the urban factor in the *p* values of the chi-square test on urban expenditures. In the results for women's education, we find (except for Ghana) that the coefficients on education are uniformly negative, significant, and large in magnitude.

The coefficients presented in Table 5 are not readily interpretable in terms of demographic impact. To assess their substantive implications, we have calculated predicted values of children ever born, with woman's age set at 40 years, for different levels of expenditure per adult in both rural and urban areas. The predictions are evaluated across the range of expenditures from the 10th to the 90th percentile. We perform similar calculations for each distinct level of women's education.

In examining these predicted levels of lifetime fertility (not shown), we find that although expenditures per adult generally have a statistically significant influence on fertility, their demographic effect is comparatively small. The implied differences in fertility between the 10th and the 90th percentiles of expenditure never exceed 0.4 children in either the negative or the positive direction. Perhaps effects of such magnitude should not be dismissed, but they do not appear to be decisively important.

When applied to women's education, the same kind of analysis reveals a strikingly different picture. Apart from Ghana, in which the women's education coefficients are insignificant, inspection of predicted fertility shows that the education effects are of clear substantive importance. In Jamaica, for example, the predicted mean fertility of a woman with postsecondary schooling is 2.82 children, whereas the prediction for women with less than secondary schooling (the omitted category) is 4.28 children. Even larger differentials are evident in Peru, where women without secondary schooling are predicted to have 5.12 children; those with secondary schooling, 3.74 children; and those with postsecondary schooling, 2.29 children. Important education effects also characterize Guatemala, Pakistan, and Tanzania.[12] These education differentials are all the more striking given that the inclusion of consumption per adult controls for the association between education and the standard of living.

Table 6 presents estimates of the fertility models in which the SLI proxies are employed in place of consumption per adult. Because the coefficients on the individual index items confound two associations—between the index item and consumption per adult, and between consumption per adult and fertility—it is not obvious that the index coefficients merit discussion. (Some of these items show a reasonably consistent association with fertility across countries—for example, water on the premises, electricity, possession of a refrigerator—but others do not.) We have argued that the principal role of these proxies is to enable chi-square tests of the null hypothesis that consumption is irrelevant. As shown in Table 6, the *p* values on the chi-square test reveal that the index items are highly significant as a group. Using these proxies, we would decisively reject the

12. In light of these differentials, the case of Ghana appears unusual indeed. Further analysis shows that in urban areas in Ghana, secondary education has an important negative influence on fertility, and middle school education has a significant, but not large, negative effect (results not shown).

null hypothesis that the true consumption coefficient is zero.[13]

Table 6 also shows that the women's education coefficients are not affected strongly, whether in sign, significance, or magnitude, by the use of the proxy SLI variables. For the most part, the estimated education effects either fall within the 95% confidence bands surrounding the preferred estimates from Table 5 or lie near these bands. At least for the countries studied here, one would not be misled about the importance of women's education to fertility if given only the results based on proxies.

We have repeated this analysis using measures of recent fertility in the sample of countries for which this is possible. The results for both expenditure and schooling are qualitatively similar to those shown above, although statistical significance is diminished.

## Child Mortality

Three of the data sets provide usable information on child mortality. Employing the Cox regression method, we have estimated proportional hazards models of mortality risk in the first five years of life. In addition to the explanatory covariates used in the fertility analyses, we consider the mother's age at birth (under 20 or over 40), the child's sex, and dummy variables for first births and high-parity (> 6) births, as well as a year of birth variable to capture trend.

Tables 7 and 8 display the results, focusing again on women's education, the consumption per adult variable, and its SLI proxies. Table 7 shows that consumption per adult has a statistically significant negative effect on mortality in urban and rural areas in Ghana, and a marginally significant effect in Guatemala. (The estimate for urban Pakistan implausibly suggests a positive effect.) As in the fertility analyses, mother's education is estimated to have little influence in Ghana, but it is associated significantly with reduced mortality risks in both Guatemala and Pakistan. In regard to magnitudes, the implications are similar to those of fertility analyses: The consumption variable alters the predicted value of ${}_5q_0$ by no more than 1 to 2 percentage points over the 10th to 90th percentiles of consumption, whereas changes in women's education have an effect of 6 percentage points in Guatemala and Pakistan.

In assessing the role of proxy variables in these mortality models, we have removed the water and toilet measures from the proxies category and have assigned them a potentially causal role. Therefore the proxy-based tests for the relevance of consumption are based only on the remaining SLI variables. These chi-square tests are shown in Table 8. For Guatemala and Pakistan, the test rejects the hypothesis that consumption per adult is irrelevant, although it fails to reject this hypothesis in Ghana.[14] Once again, the estimates of

**TABLE 7. MODELS OF CHILD MORTALITY: SELECTED COX REGRESSION COEFFICIENTS**

| | Ghana | Guatemala | Pakistan |
|---|---|---|---|
| Number of Children | 12,869 | 7,338 | 17,355 |
| Expenditure per Adult Coefficients | | | |
| Expenditure per adult (00's) | $-.064 \times 10^{-1}$ (2.22) | $-.088 \times 10^{-1}$ (1.93) | $.002 \times 10^{-1}$ (0.38) |
| Expenditure × urban | $-.042 \times 10^{-1}$ (0.86) | | $.018 \times 10^{-1}$ (1.69) |
| Urban | –.136 (1.40) | | –.067 (1.16) |
| Chi-Square Tests on Expenditure Coefficients: $p$ Values | | | |
| Both equal zero | .003 | .054 | .113 |
| Urban equals zero | .008 | | .040 |
| Women's Education Coefficients | | | |
| Primary school | .053 (0.78) | –.264 (2.95) | –.226 (2.77) |
| Middle school | .046 (0.76) | | –.513 (3.68) |
| Secondary school | .000 (0.00) | –.962 (2.79) | –.463 (3.92) |
| Chi-Square Tests on Education Coefficients: $p$ Values | | | |
| All equal zero | .786 | .001 | .000 |
| Access to Safe Water Coefficients | | | |
| Access to clean water | .128 (1.57) | .252 (2.21) | .050 (0.58) |
| Water on premises | –.370 (2.91) | –.382 (3.24) | –.102 (1.17) |
| Time to water < 30 min. | –.050 (0.80) | .495 (2.40) | .163 (1.64) |
| Toilet facility | –.023 (0.38) | –.064 (0.35) | .058 (1.01) |
| Flush toilet | –.230 (1.30) | –.174 (0.61) | –.359 (6.27) |
| Chi-Square Tests on Water Coefficients: $p$ Values | | | |
| All equal zero | .018 | .006 | .000 |

*Note:* $|Z|$ statistics are shown in parentheses.

13. The interaction of an urban dummy variable and SLI-1 is included with the other proxies in this text, but the conclusion is not affected by excluding it.

14. In the case of Pakistan, the test based on proxies for consumption decisively rejects the null, whereas the analysis shown in Table 7, using consumption, indicates that consumption is insignificant or at best marginally significant. According to the statistical theory outlined above, one would expect that proxy-based tests would reject less often than the counterpart test based on the true consumption variable. Of course, because test statistics are random variables, this is not guaranteed to occur in any given case.

**TABLE 8. COMPARISON OF MORTALITY MODELS USING PROXIES AND EXPENDITURES**

| | Ghana | Guatemala | Pakistan |
|---|---|---|---|
| Chi-Square Tests on Proxies: *p* Values | | | |
| All equal zero | .140 | .090 | .000 |
| Women's Education Coefficients Based on Proxies | | | |
| Primary school | .053 | –.217 | –.190 |
| Within confidence band around Table 7 estimate | yes | yes | yes |
| Middle school | .046 | | –.419 |
| Within confidence band | yes | | yes |
| Secondary school | .000 | –.836 | –.289 |
| Within confidence band | yes | yes | yes |
| Chi-Square Tests on Education Coefficients: *p* Values | | | |
| All equal zero | .853 | .010 | .001 |
| Water Coefficients Based on Proxies | | | |
| Clean water | .147 | .203 | .035 |
| Within confidence band | yes | yes | yes |
| Water on premises | –.316 | –.337 | –.079 |
| Within confidence band | yes | yes | yes |
| Time to water | –.070 | .488 | .152 |
| Within confidence band | yes | yes | yes |
| Toilet | –.027 | –.057 | .038 |
| Within confidence band | yes | yes | yes |
| Flush toilet | –.202 | –.148 | –.296 |
| Within confidence band | yes | yes | yes |
| Chi-Square Tests on Water Coefficients: *p* Values | | | |
| All equal zero | .120 | .026 | .000 |

women's education effects in the proxy variables model fall within the 95% confidence bands surrounding the preferred estimates from Table 7. The same is true of the estimates of the water and toilet coefficients. As in the fertility analyses, the proxy variable estimates seem to provide reliable guidance to the preferred estimates based on consumption.

## Children's Schooling

Among the determinants of children's years of schooling, both consumption expenditure and women's education make highly significant contributions. As shown in Table 9, in the otherwise diverse settings of urban Ghana, rural Guatemala, and rural and urban Pakistan, the consumption coefficient is positive and statistically significant; the coefficient for rural Ghana, although insignificant by the conventional criterion, is also positive. Similarly, the coefficients associated with women's education are positive and highly significant, again with the partial exception of Ghana.

To assess the magnitude of these effects, we have calculated predicted years of schooling for a child of age 18, a prediction that should approximate completed schooling, and have examined how such predictions vary with consumption percentiles and with the level of the woman's education. As in the cases of fertility and mortality, we find that larger effects are associated with the woman's education than with consumption expenditures. The predicted values for children's schooling, evaluated at the 10th and the 90th percentiles of consumption, differ by no more than a year of schooling. For women's education, however, a similar comparison suggests differences ranging from a low of 0.4 years in Ghana to nearly 10 years in Pakistan. The differences are not important only at the extremes; they are also substantial at intermediate levels of women's education.

A comparison of schooling estimates based on the SLI proxies for consumption is displayed in Table 10. The null hypothesis that consumption is irrelevant is rejected decisively by the proxy-based chi-square test; this result agrees with what is shown in Table 9. The estimates of the women's education coefficients reveal that, in Ghana, the proxy-based estimates lie within the confidence bands surrounding the

**TABLE 9. MODELS OF CHILDREN'S SCHOOLING: SELECTED ORDERED-PROBIT COEFFICIENTS**

| | Ghana | Guatemala | Pakistan |
|---|---|---|---|
| Number of Children | 6,697 | 2,795 | 12,498 |
| Expenditure per Adult Coefficients | | | |
| Expenditure per adult (00's) | $.029 \times 10^{-1}$ (1.64) | $.077 \times 10^{-1}$ (5.47) | $.010 \times 10^{-1}$ (4.05) |
| Expenditure × urban | $.016 \times 10^{-1}$ (0.71) | | $.047 \times 10^{-1}$ (8.54) |
| Urban | .242 (5.14) | | .127 (4.30) |
| Chi-Square Tests on Expenditure Coefficients: *p* Values | | | |
| Both equal zero | .002 | .000 | .000 |
| Urban equals zero | .002 | | .000 |
| Women's Education Coefficients | | | |
| Primary school | .002 (0.04) | .592 (11.38) | 2.478 (68.18) |
| Middle school | .089 (2.42) | | 3.930 (78.21) |
| Secondary school | .135 (3.54) | 1.356 (10.23) | 5.217 (88.78) |
| Chi-Square Tests on Education Coefficients: *p* Values | | | |
| All equal zero | .001 | .000 | .000 |

*Note:* $|Z|$ statistics are shown in parentheses.

**TABLE 10. COMPARISON OF SCHOOLING MODELS USING PROXIES AND EXPENDITURES**

| | Ghana | Guatemala | Pakistan |
|---|---|---|---|
| Chi-Square Tests on Proxies: *p* Values | | | |
| All equal zero | .000 | .000 | .000 |
| Women's Education Coefficients Based on Proxies | | | |
| Primary school | .003 | .412 | 2.288 |
| Within confidence band around Table 9 estimate | yes | no | no |
| Middle school | .091 | | 3.677 |
| Within confidence band | yes | | no |
| Secondary school | .102 | .762 | 4.921 |
| Within confidence band | yes | no | no |
| Chi-Square Tests on Education Coefficients: *p* Values | | | |
| All equal zero | .011 | .000 | .000 |

preferred estimates. In Guatemala and Pakistan, however, these estimates are smaller than the preferred Table 9 estimates and lie below the confidence bands. This finding might be taken as evidence of severe large-sample bias in the proxy estimators, but the qualitative conclusions one would draw from Table 10 are much the same as those from Table 9. In either case, a compelling argument is made for the importance of the woman's education to her children's educational attainment.

## CONCLUSIONS

On the whole, the results of this research should offer some encouragement to demographers, who have had little recourse but to rely on proxy variables for their measures of household living standards. We find that the SLI proxies are very weak predictors of consumption per adult; their partial $R^2$ values are extremely low. But when the SLI proxies are enlisted mainly to test whether consumption is relevant to behavior, they are rescued by two other factors. First, consumption expenditures per adult vary considerably; therefore even weak proxies for consumption are able to detect departures from the null hypothesis. Second, demographers are fortunate in having access to relatively large samples, and sample size further enhances the power of the proxy-based tests. With the aid of these two factors, even proxies as weak as these indices can provide useful information. They furnish the basis for tests of the relevance of consumption whose power should be acceptable in most demographic applications.

In illustrating the theory through models of lifetime fertility, child mortality, and children's schooling, we have found evidence that consumption per adult has a statistically significant effect on demographic behavior. Tests for the relevance of consumption generally reject the null hypothesis of no effect, whether based on proxies for consumption or on the variable itself. For the reasons outlined above, the proxy variables coefficients cannot reveal the magnitude of such effects, but the consumption coefficients suggest that the demographic impacts are rather small. If the effects are as small in general as our estimates indicate, the null hypothesis of no effect will often fail to be rejected, especially when that hypothesis is tested with weak proxies.

In contrast to the consumption results, in all countries save Ghana, women's education seems to exert a substantial influence on fertility, child mortality risks, and children's schooling. Because the effects of consumption per adult are controlled in these models, the education effects are remarkably strong. The case of Ghana, evidently unusual, bears further inspection. It may be that the quality of schooling in Ghana has been low, with the result that women's education is not associated as closely with demographic behavior there as in other countries (see Glewwe 1999). One would be hard-pressed to say, however, that school quality is uniformly lower in Ghana than in other poor countries such as Tanzania and Pakistan.

As we have discussed, another potential benefit of using proxy variables is to reduce the inconsistency in the $\hat{\beta}$ estimators attached to women's education and other covariates. In our limited sample of countries, we find little to suggest that the effects of women's education will be badly misestimated if proxy variables are used in place of the preferred consumption measure.

To be sure, this conclusion, and the conclusion about the relative magnitudes of the education and consumption effects, are based on a small sample of country experience and on simple behavioral models of fertility, child mortality, and children's schooling. We hesitate to suggest that the results are more generally applicable; perhaps a wider sample or a more detailed empirical investigation would overturn some of our findings. In particular, we would welcome a comparison of competing perspectives on the measurement of living standards. Although we favor viewing the SLIs as proxies for consumption per adult, the debate has ample room for alternative views. A rigorous comparison with latent variables models could prove especially instructive.

Our main substantive result is likely to withstand such scrutiny. Our estimates provide striking evidence of the varied roles played by women's education in demographic behavior; such roles appear to be separable from the direct links of education to living standards. If we have controlled adequately for living standards by using consumption per adult, the estimates suggest that education makes a decisive contribution in affecting women's cognitive abilities, attention to and receipt of information, social confidence, and autonomy in decision making. Our models do not reveal which of these factors makes the difference—perhaps all do—but they underscore their importance to demographic behavior.

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**APPENDIX TABLE A1. RESEARCH ON DEVELOPING COUNTRIES USING MEASURES OF LIVING STANDARDS PUBLISHED IN *DEMOGRAPHY* OR *POPULATION STUDIES*, 1990–1996**

| Author(s) | Title | Data Source | Measure of Living Standards |
|---|---|---|---|
| Eric Jensen | "The Fertility Impact of Alternative Family Planning Distribution Channels in Indonesia," *Demography* (1996) | Indonesia 1991 DHS | Index of durables, quality of housing |
| Narayan Sastry | "Community Characteristics, Individual and Household Attributes, and Child Survival in Brazil," *Demography* (1996) | Pesquisa Nacional Sobre Saude Materno-Infantil e Planejamento Familiar–Brasil, 1987 DHS | Total household income |
| Anne Pebley, Noreen Goldman, and Germán Rodríguez | "Prenatal and Delivery Care and Childhood Immunization in Guatemala: Do Family and Community Matter?" *Demography* (1996) | National Survey of Maternal and Child Health in Guatemala in 1987 | Occupation, woman's and spouse's education, whether woman has ever worked, presence of modern toilet facility in household |
| Pradip Muhuri | "Estimating Seasonality Effects in Child Mortality in Matlab, Bangladesh," *Demography* (1996) | Matlab Demographic Surveillance System (DSS) and 1982 Matlab Census | Receives by way of remittances or owns a radio, bicycle, watch, quilt, or lamp; dwelling space per capita; mother has no schooling; child born in Matlab treatment area |
| Ilene Speizer | "A Marriage Trichotomy and Its Applications," *Demography* (1995) | Cameroon 1991 DHS | Type of flooring; ownership of durables: radio, bicycle, television, electricity, motorcycle, car, stove, refrigerator |
| Ulla Larsen | "Differentials in Infertility in Cameroon and Nigeria," *Population Studies* (1995) | World Fertility Surveys and DHS for Cameroon (1971, 1991) and Nigeria (1981–1982, 1990) | Polygynous union (many wives indicating higher economic status), woman's and spouse's education, occupation |
| Akinrinola Bankole | "Desired Fertility and Fertility Behaviour Among the Yoruba of Nigeria: A Study of Couple Preferences and Subsequent Fertility," *Population Studies* (1995) | Surveys of Department of Demography and Social Statistics, Obafemi Awolowo University, Nigeria 1984, 1986 | Spouse's occupation: agricultural, nonagricultural, not working |
| Kofi Benefo | "The Determinants of the Duration of Postpartum Sexual Abstinence in West Africa: A Multilevel Analysis," *Demography* (1995) | World Fertility Survey for Côte d'Ivoire 1978, Ghana 1979, Cameroon 1978 | Mother's education, nonfamily work, urban residence, spouse's nonmanual occupation |
| Kenneth Bollen, David Guilkey, and Thomas Mroz | "Binary Outcomes and Endogenous Explanatory Variables: Tests and Solutions With an Application to the Demand for Contraceptive Use in Tunisia," *Demography* (1995) | Tunisia 1988 DHS | Sum of household assets |
| Renata Forste | "The Effects of Breastfeeding and Birth Spacing on Infant and Child Mortality in Bolivia," *Population Studies* (1994) | Bolivia 1989 DHS | Partner's education, mother's employment |
| Kerry Richter, Chai Podhisita, Apichat Chamratrithirong, and Kusol Soonthorndhada | "The Impact of Child Care on Fertility in Urban Thailand," *Demography* (1994) | Child Care, Women's Status, and Fertility in Urban Thailand, 1990–1991 | Spouse's occupation |

*(continued)*

*(Appendix Table A1 continued)*

| Author(s) | Title | Data Source | Measure of Living Standards |
|---|---|---|---|
| Deborah Balk | "Individual and Community Aspects of Women's Status and Fertility in Rural Bangladesh," *Population Studies* (1994) | Survey collected by the MCH-FP Extension Project of the International Centre for Diarrhoeal Disease Research, Bangladesh, 1988 | Respondent's secular education, dwelling size, landholdings, landlessness, husband a daily laborer |
| Guang Guo and Laurence Grummer-Strawn | "Child Mortality Among Twins in Less Developed Countries," *Population Studies* (1993) | Demographic and Health Surveys for 26 developing countries | Urban/rural residence, mother's and spouse's education, husband's occupation (agricultural, manual), owns car or TV |
| Cynthia Lloyd and Anastasia Gage-Brandon | "High Fertility and Schooling in Ghana: Sex Differences in Parental Contributions and Educational Outcomes," *Population Studies* (1994) | Ghana 1987–1988 LSMS | Consumption per household head |
| Andrew Foster | "Household Partition in Rural Bangladesh," *Population Studies* (1993) | Matlab Demographic Surveillance System; census data 1974–1982 | Number of items owned: radios, watches, quilts, lamps; number of cows owned; whether household receives remittances |
| Linda Adair, Barry Popkin, and David Guilkey | "The Duration of Breast-feeding: How Is It Affected by Biological, Sociodemographic, Health Sector, and Food Industry Factors?" *Demography* (1993) | Cebu Longitudinal Health and Nutrition Survey 1983–1984 | Ownership of refrigerator, gas or kerosene stove; piped water; mother worked in modern wage sector during pregnancy; spouse present in household |
| John Stewart, Barry Popkin, David Guilkey, John Akin, Linda Adair, and Wilhelm Flieger | "Influences on the Extent of Breast-feeding: A Prospective Study in the Philippines," *Demography* (1991) | Authors' survey of metropolitan Cebu, Philippines | Family's real income in top quartile |
| Deborah DeGraff | "Increasing Contraceptive Use in Bangladesh: The Role of Demand and Supply Factors," *Demography* (1991) | 1982 Matlab Socioeconomic Survey; 1984 In-Depth Contraceptive Knowledge, Attitudes, and Practice Survey | Owns land, owns boat, spouse's occupation, composition of dwelling walls, access to clean drinking water |
| Wamucii Njogu | "Trends and Determinants of Contraceptive Use in Kenya," *Demography* (1991) | Kenya Fertility Survey 1977–1978 (WFS) | Region of residence |
| John Knodel and Malinee Wongsith | "Family Size and Children's Education in Thailand: Evidence From a National Sample," *Demography* (1991) | Thailand 1987 DHS | Wealth index derived from types of vehicles owned, type of flooring, type of toilet facility |
| David Hamill, Amy Tsui, and Shyam Thapa | "Determinants of Contraceptive Switching Behavior in Rural Sri Lanka," *Demography* (1990) | Rural Family Planning Survey 1985–1986 | Type of housing and household water source |
| Martin Brockerhoff | "Rural-to-Urban Migration and Child Survival in Senegal," *Demography* (1990) | Senegal 1986 DHS | Region; mother's marital status, education, work status, occupation; spouse's occupation; toilet facilities, source of drinking water |

*(continued)*

*(Appendix Table A1 continued)*

| Author(s) | Title | Data Source | Measure of Living Standards |
|---|---|---|---|
| Michael Koenig, James Phillips, Oona Campbell, and Stan D'Souza | "Birth Intervals and Childhood Mortality in Rural Bangladesh," *Demography* (1990) | Matlab Demographic Surveillance System | Household area, mother's education |
| Abdur Razzaque, Nurul Alam, Lokky Wai, and Andrew Foster | "Sustained Effects of the 1974–5 Famine on Infant and Child Mortality in a Rural Area of Bangladesh," *Population Studies* (1990) | Matlab Demographic Surveillance System | Additive index of articles owned or received as remittances: quilts, hurricane lamps, radios, watches, cash remittances |

*Source:* See references for citations.

demographic, Health Sector, and Food Industry Factors?" *Demography* 30:63–80.

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