

# **Child Height, Household Resources, and Household Survey Methods**

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## **Abstract**

The impact of endogeneity and measurement error on the estimated effect of household economic resources on child height is demonstrated. These econometric problems contribute to uncertainty in the literature about the significance of income effects on child health and nutrition. Results are based on a household survey from Papua New Guinea, where repeated within-year observations on households allows calculation of each variable's reliability ratio. The relative importance of measurement error and endogeneity bias is shown by comparing estimates that use the reliability ratios to correct only for measurement error with instrumental variables estimates that correct for both endogeneity and measurement error bias.

**JEL: I12, O12**

**Keywords:** Child health, Errors-in-variables, Household resources, Survey methods

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## 1. Introduction

Economists are divided over the question of whether household economic resources have a significant effect on child height, which is considered the best anthropometric indicator of longer-run health and nutrition in developing countries (Thomas, Strauss, and Henriques, 1991). Studies finding no effect of either expenditures or incomes on child height include Wolfe and Behrman (1982) and Barrera (1990). Other studies find significant income effects only for older children (Thomas and Strauss, 1992; Sahn and Alderman, 1997), or only in the urban sector (Thomas, Lavy and Strauss, 1996).<sup>1</sup> Only a minority of studies can conclude, as Sahn (1994) does, that raising incomes is a key element in any effort to reduce chronic malnutrition. Consequently, interest has turned from general economic development policies to more targeted interventions, especially because variables such as mother's education appear to have a more powerful effect on child health than does income (Ruel, *et al.*, 1999).

The purpose of this note is to show, empirically, the impact of two common econometric problems – endogeneity and measurement error bias – on the estimated effect of household resources on child height. The problem of endogeneity, which occurs because household total expenditures and child health care are likely to be jointly determined (Thomas, Strauss and Henriques, 1990), is widely recognised in the literature on child height. Thus, it is now usual for models of child height to instrument expenditures (or incomes). This effort has been aided by the increased availability of multi-topic surveys – such as the Living Standards Measurement Surveys (Deaton, 1997) – because these surveys include a wider range of potential instruments (e.g., productive assets) than traditional single-topic surveys.

The problems created by errors in the measurement of household resources are less commonly discussed (Thomas, Strauss and Henriques, 1990). These errors matter especially in models of

child height because the dependent variable summarizes the history of nutrient intakes and sicknesses, so the income measures should have a similarly long reference period. Current income, typically measured with a ‘snapshot’ of a week, fortnight, or month, is an error-laden measure of long-term resources. Current expenditure is preferred because this variable reflects efforts by households to smooth their consumption. But even expenditure is a noisy measure of long-run resources (Thomas, Lavy and Strauss, 1996), and as shown below, use of this variable causes a downward bias in the estimated effect of household resources on child height. Although the treatment of measurement error has benefited from the better instrument sets available in multi-topic surveys, the underlying problem of reliably measuring long-run household resources has not been solved.<sup>2</sup> Indeed, the lack of discussion of measurement error in the child height literature may have diverted attention away from this problem.

Errors in measuring long-run household economic resources may explain some of the patterns found in the empirical literature on child height. In particular, urban households appear to have less volatile expenditures than do rural households (Gibson, 1999) which may explain why measured income effects in urban areas exceed those in rural areas (Sahn, 1994; Thomas, Lavy and Strauss, 1996). Similarly, the results presented below suggest that mother’s education may appear to have a stronger effect than income just because education is measured more reliably and so does not suffer as much downward bias.

The results are based on a household survey from Papua New Guinea (PNG), where repeated within-year observations on households allows calculation of each variable’s *reliability ratio* – one minus the ratio of the measurement error variance to the total variance. These reliability ratios allow regression estimates to be corrected for the attenuation caused by errors-in-variables (Fuller and Hidirolou, 1978), but this EIVREG estimator does not treat

endogeneity bias. Instead, the joint treatment of measurement error and endogeneity bias is carried out with instrumental variables (IV) methods, using data on household and agricultural assets as the instruments for household resources. To see the relative importance of measurement error and endogeneity bias, the EIVREG and IV estimates are compared with each other and with OLS estimates that correct for neither of these problems.

## 2. Empirical Approach

The model estimated is a reduced form demand equation for child health coming from the household's maximisation of a utility function which depends on commodity consumption, leisure, and the quality and quantity of children and is constrained by a budget constraint, a time constraint and a health production function. The demand for child health depends on a set of child characteristics  $x_j$ , household (or parental) characteristics  $x_h$ , community characteristics  $x_c$ , and a child-specific random error reflecting heterogeneity in individual healthiness  $\mathbf{e}_j$ ,

$$D_h = h(x_j, x_h, x_c, \mathbf{e}_j). \quad (1)$$

One of the main household characteristics included in  $x_h$  is (instrumented) expenditure, which acts as a measure of permanent income, so strictly speaking, equation (1) is a quasi-reduced form model (Pollack, 1969) because it does not include the exogenous determinants of income (such as productive assets). However, equations like (1) are the basis of most econometric models of child health.

The dependent variable in the model is the height-for-age  $z$ -score of an individual child, formed as  $(h - h_{med})/\mathbf{s}$ , where  $h$  is the child's height,  $h_{med}$  is the median height for the same age and sex in the reference population, and  $\mathbf{s}$  is the standard deviation in the reference population.<sup>3</sup> The child characteristics included in the model are the child's gender and age,

where age is entered as a string of dummy variables for each 12-month age bracket and it is expected that coefficients will diminish with increasing age due to the worsening of growth retardation in the early years of life (Sahn and Alderman, 1997). The household characteristics included in the model are (log) per capita expenditures, (log) household size, and the years of schooling and height of the child's mother. Household size is treated as potentially endogenous, due to the tradeoff between the quality and quantity of children.<sup>4</sup> The community variables included in the PNG survey are less detailed than many other recent surveys, so two regional dummy variables are used to capture missing community effects. The first identifies urban areas, which have accessible public health facilities and good sanitation, in contrast to rural parts of the country.<sup>5</sup> The second dummy variable identifies highland regions, where the access to public services lags behind most other parts of the country.<sup>6</sup>

Two of the estimation methods used (OLS and IV) need no description but the regression estimator corrected for attenuation (EIVREG) is less well known so it is described here. Let the model to be estimated be:

$$\begin{aligned} \mathbf{y} &= \mathbf{X}^* \mathbf{b} + \mathbf{e} \\ \mathbf{X} &= \mathbf{X}^* + \mathbf{U} \end{aligned}$$

where  $\mathbf{X}^*$  are the true values,  $\mathbf{X}$  the observed values and  $\mathbf{U}$  the measurement errors. Let  $\hat{\Sigma} = (1/N)\mathbf{X}'\mathbf{X}$  denote the moment matrix of the observed  $\mathbf{X}$  matrix and  $\mathbf{\Omega}$  the covariance matrix of the measurement errors in the  $\mathbf{X}$  variables. With white noise measurement errors,  $\hat{\mathbf{\Omega}}$  is a consistent estimator of  $\mathbf{\Omega}$ , obtained as the Hadamard product of the moment matrix  $\hat{\Sigma}$  and a diagonal matrix with elements  $(1-I_i)$ , where  $I_i$  is the reliability ratio of the  $i$ th variable (here denoted as  $x (=x^*+u)$ ). This reliability ratio is the proportion of the variation in  $x$  that is due to variation in the true value,  $\mathbf{s}_{x^*}^2 / (\mathbf{s}_{x^*}^2 + \mathbf{s}_u^2)$ . If  $\mathbf{b} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y}$  is the OLS estimator, then the estimator corrected for attenuation is  $\hat{\mathbf{b}} \equiv \hat{\Sigma}_*^{-1}\hat{\Sigma}\mathbf{b}$  where  $\hat{\Sigma}_* = \hat{\Sigma} - \hat{\mathbf{\Omega}}$  (Iwata, 1992).

### 3. Data

The data come from the 1996 Papua New Guinea Household Survey, which covered a random sample of 1200 households in 120 rural and urban communities. Details of the survey design can be found in Gibson (1999), but one notable point is that the sample was clustered, stratified and weighted, so all results presented here take account of these sample design effects.<sup>7</sup> Each household was visited twice over a two-week period and on each visit anthropometric measurements (height and weight) were made on all children below age five ( $n=969$ ), and on the available parents (usually mothers) of these children. The age of each child and demographic and educational information on other household members was also recorded. The expenditure estimates made by the survey include all food and other frequent expenses during the two-week interview period,<sup>8</sup> plus infrequent expenses (obtained from a 12-month recall) and an estimate of the flow of services from durable assets and owner-occupied dwellings. Complete data are available on 729 children and their households.

An unusual feature of the survey was that twenty of the survey clusters were chosen as a “longitudinal sub-sample” and households in these clusters were revisited approximately seven months after the first interviews. All parts of the survey, including the expenditure recall, were gathered again during these revisits. The correlation between these two sets of observations on the same household allows the reliability ratio of each variable to be established. Let  $x^1$  be the first observation on a given household’s expenditures, and  $x^2$  be a repeated observation on the same household, some months later. Then if errors are assumed to be white noise,

$$\begin{aligned} r(x^1, x^2) &= \frac{\text{cov}(x^* + u^1, x^* + u^2)}{\sqrt{\text{var}(x^* + u^1) \bullet \text{var}(x^* + u^2)}} \\ &= \frac{\text{var}(x^*)}{\sqrt{\text{var}(x^1) \bullet \text{var}(x^2)}} \end{aligned}$$

because  $u^1$  and  $u^2$  are uncorrelated with each other and with the true values. The correlation coefficient gives the ratio of the variance in the true variable to the (geometric) average variance of the repeatedly observed variables, and hence serves as an estimate of the reliability ratio for that particular variable in the full sample, as long as the households in the longitudinal sub-sample are representative of the full sample.<sup>9</sup>

Figure 1 reports the reliability ratios for the four household and parental characteristics included in the model – the log of annual per capita expenditures (PCE), log household size, mother’s years of schooling, and mother’s height. It is clear that maternal height and schooling levels are measured with the greatest reliability ( $r=0.93-0.96$ ) because for adults these variables are unlikely to change over a six month period so the imperfect reliability only reflects observer error. On the other hand, per capita annual expenditures are measured with the least reliability ( $r=0.66$ ) because a large component of the measured variable is a short-term (i.e., two-week) recall of food and other frequent expenses, and households are evidently unable to perfectly smooth their consumption over the months of the year.<sup>10</sup> The instability in household size is also interesting, but may be particular to PNG because it is a tradition in that country to host extended family members for visits that can last months or years so measured household size will depend on whether any of these long-term guests have arrived or departed.

#### **4. Results**

The estimation results are reported in Table 1, along with the means and standard deviations of the explanatory variables. The other notable descriptive statistics are that, on average, the height of children in the sample is only 92.3 percent of the median height in the U.S. for the same age and sex, and the average  $z$ -score is  $-1.95$ . A common indicator for stunting is a

$z$ -score below -2, and according to this indicator, 47.3 percent of children in the sample are stunted, so the setting is one where child malnutrition is a significant problem.

The OLS estimates in the second column of Table 1 are subject to both errors-in-variables and endogeneity biases. With those caveats in mind, the results suggest that the standardised height of young children rises with per capita expenditures and with maternal schooling and height. Children are also taller, for their age and gender, in urban areas but shorter in the highland areas, and growth appears to falter with age, compared with the growth pattern in the reference population. The only two explanatory variables in the OLS model that are not statistically significant are household size, which may be affected by endogeneity (see below) and the gender of the child. Turning from statistical to economic significance, the OLS results suggest that per capita expenditures and mother's schooling exert an equal impact on child health: a standard deviation increase in each variable would raise the height-for-age  $z$ -score by 0.14 points.

The results change greatly once account is taken of the differing reliabilities of measurement of the explanatory variables, using the EIVREG estimator. The estimated effect of per capita expenditures more than doubles, while the effect of maternal education falls and becomes statistically insignificant. A standard deviation rise in expenditures now appears to raise the height-for-age  $z$ -score by 0.31 points, compared with a rise of less than 0.10 points for a standard deviation increase in maternal schooling. The other changes include the increased, but still statistically insignificant, coefficient on household size, and the decreased and statistically insignificant urban dummy. This change in the urban dummy likely results from the improved measurement of the income effect because average per capita expenditures are twice as high in urban areas and the height-for-age  $z$ -score is 1.2 points higher.

The treatment of both measurement error and endogeneity biases, using the IV estimator, results in a further small rise in the measured effect of household economic resources and a fall in the effect of maternal schooling and height. The instruments used include a dummy for whether the dwelling roof was iron, and the total floor area and average area per room of the dwelling. Other instruments were dummies for whether any household durable goods or agricultural capital goods were owned, a quadratic in the (log) total value of durable goods owned, and the number of pigs owned, where pigs are an important store of wealth.<sup>11</sup> To see whether the results were sensitive to the potential endogeneity of household size, the model was re-estimated with household size treated as an exogenous variable and this caused only a slight change in the estimated coefficient on  $\ln(\text{PCE})$ , raising it from 0.544 to 0.589. If household size is excluded from the model entirely, the coefficient on  $\ln(\text{PCE})$  goes to 0.598.

## **Conclusions**

This note has shown that measurement error bias accounts for much of the difference between OLS and IV estimates of the effect of household economic resources on child height-for-age in the developing country of Papua New Guinea. This measurement error occurs because household's cannot perfectly smooth their consumption, so short-period recalls of expenditures are noisy measures of long-run resources. However, the literature in this area is dominated by discussions of endogeneity, which occurs because household consumption and child health care are jointly determined. This emphasis in the literature may divert attention away from the need to develop household survey methods that are better able to measure long-run household economic resources. This imperfect measurement may contribute to uncertainty about whether household economic resources have a significant effect on child height.

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**Table 1: Determinants of Standardized Child Height in Papua New Guinea**

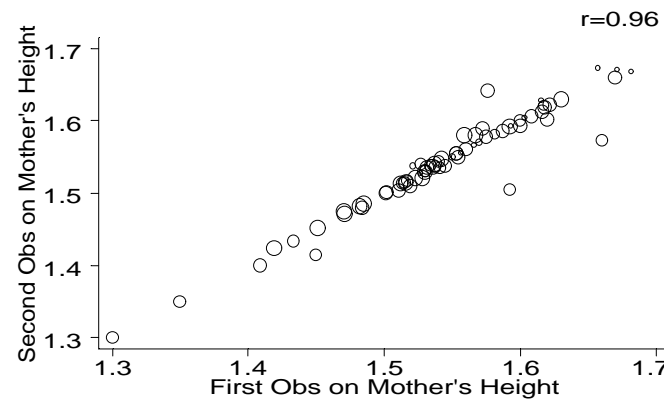
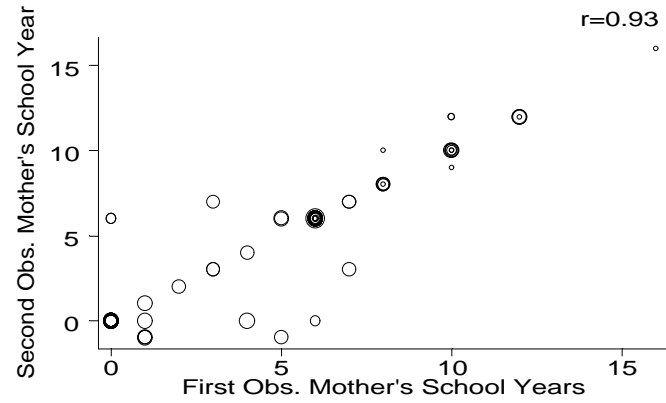
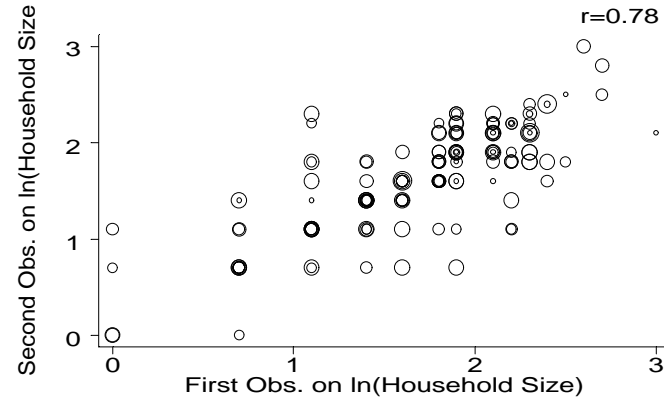
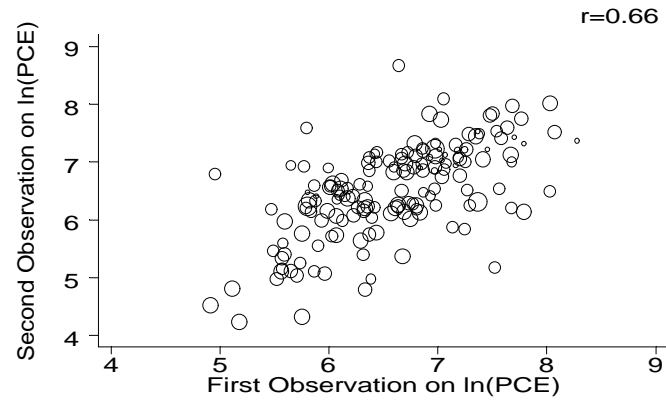
	Mean <sup>a</sup>	<i>OLS</i>	<i>EIVREG</i>	<i>IV</i>
ln (PCE) <sup>*b</sup>	6.23 [0.76]	0.182 (2.02)	0.408 (1.92)	0.544 (1.79)
ln (household size) <sup>*</sup>	1.88 [0.43]	0.137 (0.84)	0.320 (1.21)	0.480 (0.83)
Mother's school years	3.15 [3.74]	0.036 (1.95)	0.026 (1.15)	0.019 (0.86)
Mother's height (cm)	152.98 [6.66]	0.052 (7.25)	0.049 (6.01)	0.044 (3.88)
Urban dummy var.	0.15 [0.36]	0.488 (2.92)	0.291 (1.36)	0.178 (0.71)
Highlands dummy var.	0.35 [0.48]	-0.699 (3.14)	-0.783 (3.02)	-0.842 (3.26)
Child 12-24 month dummy	0.21 [0.41]	-0.764 (3.32)	-0.792 (3.43)	-0.811 (3.44)
Child 25-36 month dummy	0.21 [0.41]	-0.864 (3.73)	-0.871 (3.78)	-0.873 (3.70)
Child 37-48 month dummy	0.22 [0.41]	-0.900 (4.00)	-0.926 (4.10)	-0.945 (4.17)
Child ≥ 48 month dummy	0.13 [0.33]	-0.996 (4.21)	-1.003 (4.26)	-1.007 (3.94)
Male child dummy	0.54 [0.50]	-0.130 (1.29)	-0.156 (1.52)	-0.171 (1.57)
Constant		-9.199	-8.848	-8.255
$R^2$		0.240	0.248	0.219
$F$ -test <sub>(11,77)</sub>		18.92	19.13	16.34

*Note:* Dependent variable is the height-for-age  $z$ -score, based on NCHS standards.  $N=729$ . Numbers in ( ) are  $t$ -statistics, corrected for clustering, sampling weights and stratification. Endogenous variables are indicated by \*.

<sup>a</sup> Weighted estimates, with weights reflecting the number of households represented by each observation and standard deviations in [ ].

<sup>b</sup> Kina per year, at national average prices, where the value of the regional poverty line is used as the spatial price deflator and K1.3=US\$1 in 1996.

Figure 1: Comparison of Two Reports on Each Variable



## Notes

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<sup>1</sup> Using the same data from Côte d'Ivoire, Sahn (1994) finds significant income effects in both rural and urban sectors but the estimated effect in urban areas is twice as large as in rural areas.

<sup>2</sup> The original aim of household surveys – measuring mean expenditures and budget shares over all households – may be at fault here, because for this aim short reference periods are appropriate if the sample is spread evenly over the year. One innovation in some Living Standards Measurement Surveys is to obtain estimates of annual expenditures by asking about the number of months in the year that each item is purchased, the usual number of purchases per month and the usual value of each purchase. However, comparison of these estimates with more typical short reference period estimates has been restricted to means and variances (Deaton, 1997), rather than to the effect on regression slopes.

<sup>3</sup> The reference standards come from North American multiethnic data of the National Center for Health Statistics (NCHS) but they are applicable to developing countries (and recommended by the World Health Organization) because children from high-income households in those countries show the same age-related body stature (Gross, *et. al.*, 1996).

<sup>4</sup> Only a few studies in the child height literature, such as Sahn (1994), include household size because of concerns about finding suitable instruments. But household size usually enters indirectly as the denominator for per-capita expenditures, which has the added disadvantage of imposing an untested homogeneity assumption.

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<sup>5</sup> Only 15 percent of the PNG population lives in urban areas, so the sample of urban children is too small to allow the model to be estimated separately for urban and rural sectors.

<sup>6</sup> Previous analyses of child growth patterns in PNG have found that children in the highlands are shorter but heavier than children in the lowlands, which may reflect dietary, environmental or genetic factors (Smith, *et. al.*, 1993).

<sup>7</sup> All results reported were estimated with *Stata* version 6.0 (StataCorp, 1999).

<sup>8</sup> Self-produced foods, net gifts received and food stock changes were given imputed values based on respondent reports but estimates of average expenditure are unchanged if these respondent-reported unit values are replaced with average market prices (Gibson and Rozelle, 1998).

<sup>9</sup> Gibson (1999) shows that there is no statistically significant difference between the average value of household characteristics for the longitudinal sub-sample compared with the remaining households.

<sup>10</sup> Items covered by short-term recall comprise 81 percent of the average household budget.

<sup>11</sup> These instruments raises the  $R^2$  in the first stage regression for  $\ln(\text{PCE})$  from 0.29 to 0.41 and for  $\ln(\text{household size})$  from 0.04 to 0.17. The  $F$ -tests for excluding the instruments were  $F_{(8,87)}=14.7$  and  $F_{(8,87)}=15.7$ . A test of the over-identifying restrictions supported the validity of the instruments, with  $\chi^2_{(6)}=9.4$ .