Aldo Benini

# The Wealth of the Poor

*Simplifying living standards measurements with Rasch scales?*

## Summary

Evaluating poverty reduction requires repeated measures of the living standards of the poor. Traditionally, surveys collected data on household income or expenditure. These estimates require extensive data on each surveyed household. In recent years, measures derived from durable household goods and from access to services have been tried out as substitutes for income or expenditure-based ones.

**A monitoring officer of "RDRS Bangladesh" is interviewing a member of a neighborhood group affiliated with this NGO. The lady works with (and probably owns) a sewing machine, an item used in wealth indices assuming that its presence is reliably communicated and discriminates well between poorer and less poor households.**

However, while these wealth scales economize on data collection, their analysis has not usually been less complex. It calls for statistical expertise that local survey-implementing organizations often lack. A different technique, based on Rasch scales, has properties that make it is easy to apply and evaluate. It can make wealth measurement more accessible to local stakeholders.

The precondition is that the selection of household goods and services used in the scale must be pre-validated. I demonstrate the power of a simple 10-item scale with data from a large household survey in Bangladesh.

# Introduction

In household surveys concerned with poverty and its reduction, the measurement of living standards is a core component. Several international survey traditions have built up an impressive body of theory and methodology in this field. Best known are the Living Standards Measurement Surveys (LSMS) and the Demographic and Health Surveys (DHS). Their data collections from numerous countries are so rich and so similar in design that more and more comparative analyses have appeared. Most recently, Banerjee and Duflo (2007) have offered a very readable and instructive summary, *"The Economic Lives of the Poor"*.

These survey traditions have known steep learning curves also in their methodologies. One of the earlier debates was about income vs. consumption measures and their adequacy to capture chronic or transient poverty. Reliable measurement of either variable, however, was complex (Grosh and Glewwe 2000). In recent years, and more so after Filmer and Pritchett's (2001) *"Estimating wealth effects without expenditure data"*, household wealth measures have come into favor as simple living standard proxies.

These wealth measures combine data on durable household goods and use of services. This data assumedly is easy, quick to collect and reliable because it necessitates few questions; and these elicit yes-no answers ("Do you have a radio?") or a choice from among very few commonly known options ("What kind of toilet does your family use?"). The validity of such measures has been investigated with data from several countries (Rutstein and Johnson 2004).

The statistical treatment of this kind of data, however, is not straightforward. It is certainly beyond the analytical capacity of most local survey implementing organizations. Filmer and Pritchett and others have used ordinary principal component analysis. They have been criticized for this choice by Kolenikov and Angeles (2004). The method that these authors favor – polychoric principal components – is at the fingertips of even fewer analysts (they did make available an implementation in STATA 8).

The coexistence of easy data collection segments (as far as living standard data are concerned) and of difficult analysis to compute a final measure fits well with the typical highly stratified expertised system of development research and aid (see, with the example of the World Bank, Lera St. Clair 2004). This can be questioned in the context of rapid assessments and of participatory assessments. Is it possible to simplify further, both in data collection and in analysis, without trading off too much of the validity and precision that the wealth measure tradition has acquired?

Ideally, a wealth measure should be easy to assemble *and* analyze locally, such as by the monitoring and evaluation staff of development NGOs, by local research groups, or by citizen groups aided by them. Survey quality standards would require also that data on included items be reliable, and the compound measure be strongly correlated with already validated (possibly more complex) measures. The simplified measure should also be easy to calculate, perhaps with a help of a simple scoring rule.

## Strategies for a simpler index

A simpler wealth measure could be built following one or several of these strategies:

- Collecting fewer items
- Collecting items with fewer categories
- Simplifying the rules for combining the items into the final index

Each of these strategies has its downsides too. Reducing the number of questions asked about different wealth items may result in the loss of precision if items typically acquired within a certain stage of household asset growth are deleted, and in their lieu too many redundant ones retained. Some durable household goods come in distinct and (for living standard measurements) significant quality grades. For example, the difference between a sanitary latrine and an open latrine may be just as important as, or more important than, the difference between an open latrine and no latrine. Prematurely reducing the question (or the analytic use of the response) to a simple "Household has latrine – yes/no" alternative gives away valuable information. Inappropriate index formation may compromise the validity of the measure, by distorting the weights that different items should be assigned.

In order to avoid those pitfalls, simplified measures should be constructed from existing large living standards data sets and their household wealth measures already validated across several surveys. To this end, one may explore smaller sets of variables contained in the larger initial set and examine the loss of predictive power against the validating variable. I am doing this as an initial demonstration, using data from Bangladesh, hoping to later re-evaluate the simplified tool against other data, including household income data, collected elsewhere in the country.

In addition to reducing the number of items, two more simplifications can be used:

- Reducing the response categories to binary yes/no alternatives
- Using the count of all questions answered "Yes" as a preliminary household wealth index

The analytic vehicle for this is the Rasch scale, a statistical model that is much more popular in psychology and educational testing (Embretson and Hershberger 1998) than in poverty research (for two exceptions, however, see Winship and Jencks 2002: ; Fusco 2005). In simple words, the Rasch model follows the basic idea that when we ask a sufficiently large number of subjects a sufficiently large number of questions related to the same construct (e.g. mathematical intelligence, or purchasing power), then the response pattern will yield measures for the ability of the subjects as well as for the relative difficulty of each item.

This concept is intuitively applicable to the growth of household assets as poor people work their way out of poverty. For example, most, but not all, households will own one or several beds and be in a rainproof dwelling before they acquire a TV set. Of course, the additional difficulties in moving from step A to B and then from B to C may differ. In a simple scenario, members of most households with annual incomes of USD 1,000 and more may no longer sleep on the floor, most of those making USD 2,000 and more may afford to rent homes with good roofs, but only those making USD 4,000 or more may have TV in their majority.

The Rasch scale presumes an underlying ability to produce the observed items. For example, the – observed or assumed – household income stream over several years is at the origin of the durable goods that the visiting data collector may observe (with his own eyes or by administering a questionnaire). In Rasch lingo, the underlying ability is known as the "latent trait" and is inferred from the pattern of response. The "Rasch score", by contrast, is the simple count of items present, or, in the interview perspective, the number of item questions answered "Yes".

The great attraction of the Rasch scale, in a participatory research perspective, is that the score and the latent trait are in a simple mathematical one-to-one relationship. All individuals with the same score have the same estimate of the latent trait. For example, if a survey probes for the presence of ten distinct durable goods, and Household A reports only these three: Bed, bicycle, refrigerator, while Household B owns a bed, telephone and TV only from among the same ten-item list, then A and B have the same score of 3 and are estimated to have the same ability to acquire and retain durable goods currently.

The consequence is obvious: Since the score captures all the relevant information regarding the latent trait (Hardouin 2007b: 23), it should be more than satisfactory for the purpose of providing ranks, which require only information on order and not magnitude. In other words, a count of the household goods present from the list is enough to assign the household to a wealth rank. Households can be assigned to poorer and less poor groups on the basis of the score alone although the substantive interpretation of such grades as "very poor", "poor", etc., "rich" depends on additional knowledge. Since calculating the Rasch score is a very simple operation, it can be done locally and immediately; and a rough wealth ranking or other uses of the score in survey analysis can proceed without outside statistical support. The latent trait and other more sophisticated statistics can be calculated later, or not at all, depending on needs and the availability of expertise.

However, score equivalence – household A and B in our example have the same underlying ability – holds only if the items included in the Rasch scale relate to the same dimension. Tests for item suitability too require statistical expertise. The objective therefore is to pre-validate a scale – a set of binary variables speaking to the same topic – using a recognized survey dataset and then apply it in subsequent surveys.

## DHS Bangladesh 2004

Almost two hundred Demographic and Health Surveys (DHS) have been carried out in several dozen countries for over twenty years, are nationally-representative household surveys with large sample sizes (usually between 5,000 and 30,000 households). (http://www.measuredhs.com/). Many of the datasets are available to interested researchers by ORC Macro, a research firm that has played a key role in the development and expansion of these surveys.

In Bangladesh, six surveys were carried out between 1994 and 2004. The 2004 survey (NIPORT et al.) collected data on 10,500 households. For the purposes of this paper, we concern ourselves only with a very small segment of the data, chiefly those used in the wealth index construction (the background segment from the survey report is given on page 11 below).

Some of the variables used by DHS were not binary. I could not find the recoding rules by which DHS transformed them and passed them to the algorithm used to compute the index. Similarly, I could not locate a few of the variables used (e.g., "household has some servants") in the data table. For the purposes of the Rasch analysis (using the "raschtest" procedure that Hardouin, op.cit., offered in STATA 8), I have dichotomized variables with multiple categories. These are the four with the attribute "Good" in the table below. For example, a household is coded as living in a dwelling with "good walls" if the primary wall material in the DHS codes was either "tin", "finished", or "cement / concrete / tiled".

**Table 1: Durable household goods and their prevalence in DHS 2004 sample households**

| Item | Urban | Rural | All |
|---|---|---|---|
| Good water | 99% | 97% | 97% |
| Cot or bed | 94% | 91% | 92% |
| Good roof | 96% | 90% | 91% |
| Watch or clock | 79% | 62% | 66% |
| Chair or bench | 68% | 64% | 65% |
| Table | 65% | 61% | 62% |
| Some land (other than homestead) | 38% | 56% | 52% |
| Good walls | 70% | 47% | 52% |
| Electricity | 77% | 30% | 41% |
| Radio | 37% | 29% | 30% |
| Almirah | 47% | 24% | 29% |
| Bicycle | 18% | 26% | 24% |
| Good toilet | 48% | 16% | 23% |
| Television | 49% | 16% | 23% |
| Sewing machine | 13% | 3% | 5% |
| Telephone | 16% | 2% | 5% |
| Motorcycle or scooter | 4% | 1% | 2% |

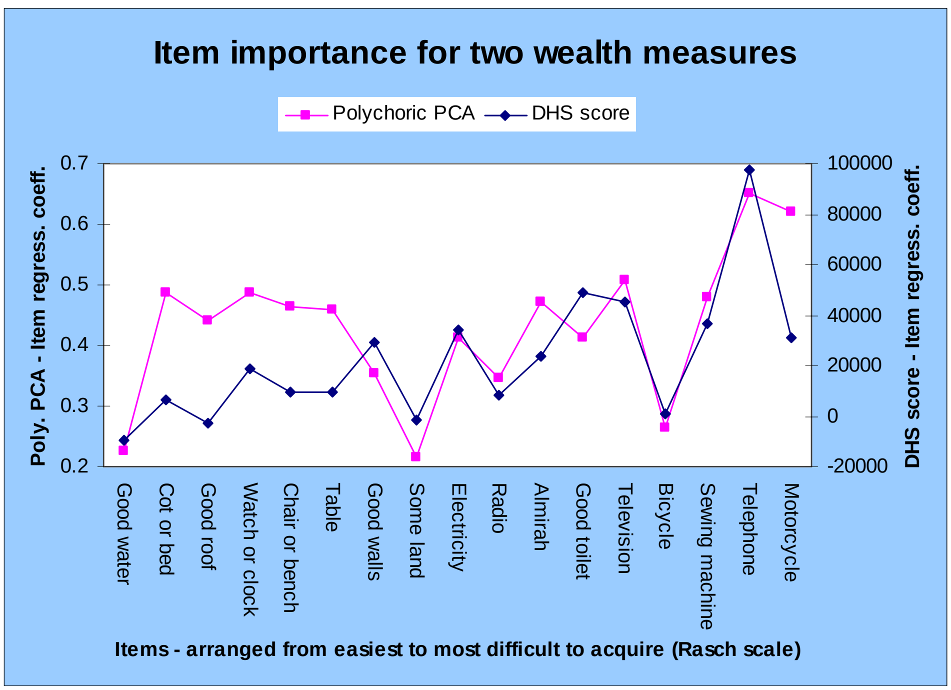
It is obvious that there are gaps between the prevalence levels of the 17 items. There is a wide one yawning between "good roof" and "watch or clock". There is, although only for rural households, a steep drop from "good walls" to "electricity". There is another gap separating the prevalence of TV from that of sewing machines. This is not ideal for scale construction, but generally survey designers have little control over the spacing unless the item frequencies are known from earlier statistics.

The DHS data table holds two wealth indicator variables, one being the factor score from an ordinary principal components analysis, the other the classification of households by quintiles. At this point, I need to quickly digress into some technicalities the results of which I will use for the simplification of the Rasch scale. Readers not interested in these arcane matters may skip to the diagram below.

As mentioned earlier, the use of ordinary PCA on binary and ordinal variables has been criticized by Kolenikov and Angeles (2004: , op.cit.). I have performed the alternative procedure that they recommend (polychoric PCA) on the 17 binary variables that I was able to locate or construct from the DHS data. This model produces three components with eigenvalues greater than one, but the first is so much stronger that it alone needs to concern us. It explains 47 percent of the variance. Unfortunately, I have not found documentation on the PCA that the DHS statisticians used and thus cannot compare the polychoric component statistics to the loadings that they obtained using the ordinary flavor.

Regardless, I then performed two regressions on the set of 17 variables, first of the polychoric PCA first-component score, then of the DHS score (which in the publicized data set had been rescaled). The results – regression coefficients that express the importance of each item for the wealth score[1] - are graphically displayed here:

**Figure 1: The relative importance of 17 items for two household wealth indices**



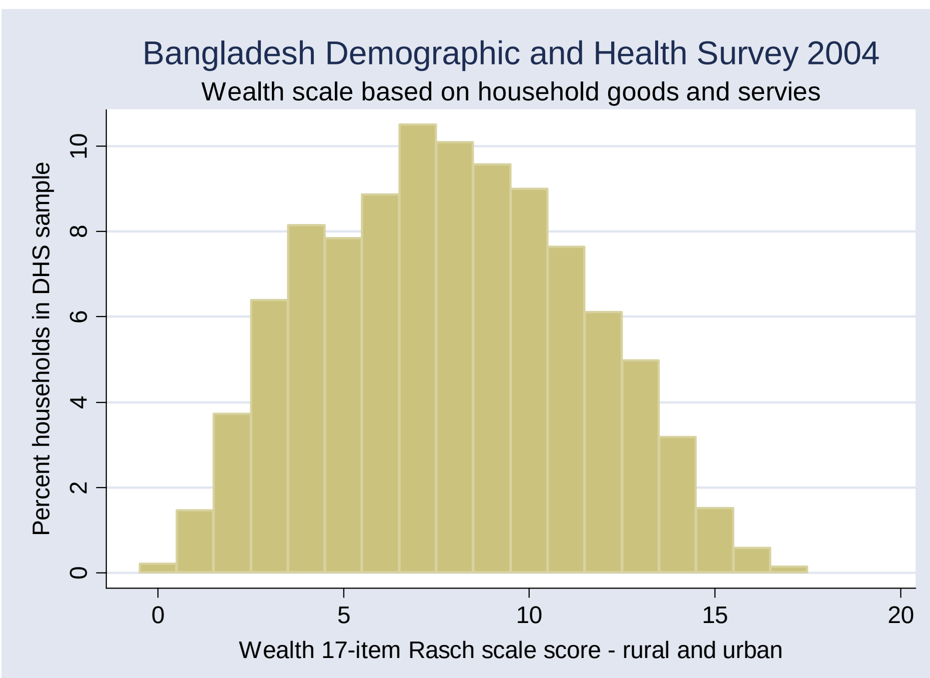

[1] The polychoric PCA factor score is nothing else but a linear combination of the 17 variables on which it is based, and therefore is completely explained by them. The same set accounts for 83 percent of the DHS score variance. The residuals are due to omitted variables (I did not have the whole set used by DHS), dichotomization of some ordinal ones, and the non-linear (normalization) rescaling by DHS.

The 17 items are arranged in the order of difficulty that the Rasch analysis revealed for their acquisition – from access to good water (which, in Bangladesh, is almost universal, not considering here the problem of arsenic contamination) to motorcycles, the possession of a slim minority of richer households. It is conspicuous that, starting from “household dwelling has good walls” the two line graphs follow each other fairly closely, with the exception of the coefficients of “motorcycles” at the far right. This is not the case of the left-side third of the items, which holds the items that poor people find easier to acquire. In this region, the blue line runs much lower than the red, with the exception of the first item, “access to good water”. Apparently, ordinary PCA downplays the importance of highly prevalent items. In other words, the DHS score is less sensitive to items that discriminate in the lower range of the wealth spectrum.

I let this graph, and the earlier frequency table, guide the selection of items that are to be eliminated from the Rasch scale item sets step by step. Candidates for exclusion are those items that were poorly associated with the first component (statistically speaking) or, if you like, with the wealth dimension (substantively speaking). Good water access is more the result of public policy in Bangladesh than of individual household wealth. Land ownership is important, but in a fast diversifying occupational structure, many households have advanced outside land ownership. Bicycles are not closely associated because of urban / rural differences and because households which owned some bicycles may have disposed of them when they could afford a motorcycle. This, of course, is speculation, just as when we conjecture that the effect of radio ownership is relatively weak because of upgrading to TV.

## Rasch analysis of 17 DHS 2004 wealth indicators

**Table 2: Distribution of the Rasch score, all 17 item scale**



The Rasch scale analysis worked out for 10,437 households that presented complete data in the 17 variables. The percentwise histogram of the 18 groups – from score 0 to score 17 – shows a somewhat normal distribution (graph on previous page).

The latent trait – the ability to acquire the items – is not defined at the extremes because the category of those without any items is a mix of households of indiscriminately low ability, and similarly the ability of the richest (who owned all 17 items) varies in ways that the data cannot determine. But the number of households in these score groups is very low (22 and 15), and for ranking purposes they could be assigned an artificial ability value, smaller than -4.58 for zero scorers, and larger than 4.99 for the top group.

**Table 3: Rasch score and ability parameters**

| Score | Ability parameter | Households |
|---|---|---|
| 0 | | 22 |
| 1 | -4.58979 | 154 |
| 2 | -3.46174 | 391 |
| 3 | -2.59867 | 669 |
| 4 | -1.88293 | 854 |
| 5 | -1.28611 | 822 |
| 6 | -0.77095 | 929 |
| 7 | -0.30516 | 1100 |
| 8 | 0.13334 | 1057 |
| 9 | 0.56028 | 1003 |
| 10 | 0.98918 | 943 |
| 11 | 1.43504 | 800 |
| 12 | 1.91753 | 640 |
| 13 | 2.4638 | 521 |
| 14 | 3.10915 | 333 |
| 15 | 3.90289 | 159 |
| 16 | 4.99471 | 62 |
| 17 | | 15 |

At first sight, the ability increments from score value to score value are not too dramatically different for a good scale – about 0.4 in the center, and 1.1 at the extremes. The latent trait has good predictive power for the DHS factor score; based on a local regression that models a non-linear relationship, the ability parameters account for 74 percent of the latter's variance.

Other tests later revealed that three items among the 17 were not suitable for a unidimensional scale[2], but here we are chiefly concerned with simplification.

What would happen if we reduced the number of items in the Rasch scale, in order to save on data collection, or to trade off interview resources to other subjects?

[2] See the Mokken scale analysis in the appendix.

We conduct this experiment by retaining at first 10 of the 17 items, then only 5, the ones shown in gray in this table:

**Table 4: Items retained in the reduced Rasch scales**

| Item | Prevalence in DHS sample | Initial 17-item scale | 10-item scale | 5-item scale |
|---|---|---|---|---|
| Good water | 97% | | | |
| Cot or bed | 92% | | | |
| Good roof | 91% | | | |
| Watch or clock | 66% | | | |
| Chair or bench | 65% | | | |
| Table | 62% | | | |
| Some land | 52% | | | |
| Good walls | 52% | | | |
| Electricity | 41% | | | |
| Radio | 30% | | | |
| Almirah | 29% | | | |
| Bicycle | 24% | | | |
| Good toilet | 23% | | | |
| Television | 23% | | | |
| Sewing machine | 5% | | | |
| Telephone | 5% | | | |
| Motorcycle | 2% | | | |

Elimination, as explained above, was guided chiefly by looking at the coefficients in the regression models and out of concern to maintain reasonable spacing across the prevalence or item difficulty spectrum.

The results are telling. With 10 items retained, the ability parameters of the Rasch scale exhaust 82 percent of the DHS score variance, slightly better than in the full 17-item scale. However, halving the number of items down to five reduces the R-square to a meager 0.58.

In other words, there is simplification and oversimplification. From these results – which are based on one data set only – it appears that dichotomization and use of the simple Rasch score – the count of items present in the household – were productive. Reducing the item set to roughly two third the number of original items did not result in a loss of predictive validity. Reduction by two thirds would be an oversimplification.

At the same time, a Rasch score is a simple measure, but no simple magic wand. Notably, some of the traditional poverty groupings, such as deciles or quintiles, cannot be exactly formed on the basis of the score. The 10-item score has a maximum of 11 unique values; the DHS wealth factor score, as a continuous variable, has 5,598 unique values realized in this sample! Groupings that try to approximate predefined ranges or n-tiles, such as the wealth quintiles of DHS, are therefore imprecise, as this cross-tabulation shows.

**Table 5: Crosstabulation of Rasch score groups and DHS wealth quintiles**

| Rasch scores | | | | DHS wealth index | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Group | Score range | N | Percent | Poorest | Poorer | Middle | Richer | Richest | Total |
| 1 | 0-2 | 2,179 | 21% | 74.1% | 21.9% | 3.3% | 0.7% | 0.0% | 100% |
| 2 | 3 | 1,867 | 18% | 26.0% | 49.5% | 20.2% | 3.8% | 0.5% | 100% |
| 3 | 4 | 1,802 | 17% | 2.1% | 29.7% | 50.1% | 15.7% | 2.4% | 100% |
| 4 | 5-6 | 2,424 | 23% | 0.0% | 2.1% | 23.7% | 53.5% | 20.7% | 100% |
| 5 | 7-10 | 2,209 | 21% | 0.0% | 0.0% | 0.1% | 13.0% | 86.9% | 100% |
| Total | | 10,481 | 100% | 20.4% | 19.0% | 18.4% | 18.7% | 23.6% | 100% |

More fundamentally, of course, neither wealth indices following the Filmer-Pritchett line nor Rasch scale are a viable substitute for income or expenditure data when detailed dynamic or composition analysis of household budgets is needed.

# Conclusion

With only 10 items – some of which require a yes/no-style question (“Is your home connected to the electricity net?”), others are derived from responses to a multiple choice question (“What kind of toilet does your family use?”) -, a measurement of household wealth seems feasible that reasonably approximates the values calculated with more extensive data and more sophisticated methods. The wealth score based on these 10 items is extremely simple – the count of the items present in the household.

The selection of these items, however, is the result of a re-analysis of a large data set that used items and methods tested in numerous other surveys. The reduced Rasch scale with 10 items will need to be tested in other surveys in Bangladesh, particularly such as estimate annual household incomes, against which the score can then be calibrated. It is likely that the NGO RDRS Bangladesh will collect data in 2007 as part of their panel surveys of program participants that will permit such a test.

If such a simple measure is found good enough an estimate of a household’s relative wealth position, both data collection and some analysis forms can be placed at a reach of actors closer to, and perhaps even with some representation from, the surveyed communities and households. One need not be as radical as to expect seamless integration with such participatory tools as wealth ranking done in grassroots meetings. Sample surveys and participatory assessments thrive in different, if sometimes interacting traditions. But even small steps in conferring enhanced analytic possibilities to local organizations seem desirable in themselves.

# Appendix

### *The DHS wealth index*

The DHS Bangladesh 2004 report explains the wealth index s follows (NIPORT et al.: Chapter 2, 23):

> 2.7 WEALTH INDEX
> In this report, an index of household economic status was created and used as a background characteristic with information on household ownership of assets and use of selected services.[1] The economic status index used here was developed and tested in a large number of countries in relation to inequities in household income, use of health services, and health outcomes (Gwatkin et al., 2000). It is an indicator of the level of wealth that is consistent with expenditure and income measures (Rutstein, 1999). The wealth index was constructed using principal components analysis (Rutstein and Johnson, 2004). Asset information was collected with the *2004 BDHS Household Questionnaire and covered information on household ownership of a number of consumer items, ranging from a television to a bicycle, as well as dwelling characteristics, such as source of drinking water, sanitation facilities, and type of material used for flooring.* Each asset was assigned a weight (factor score) generated through principal components analysis, and the resulting asset scores were standardized in relation to a normal distribution with a mean of zero and standard deviation of one (Gwatkin et al., 2000). Each household was then assigned a score for each asset, and the scores were summed for each household; individuals were ranked according to the total score of the household in which they resided. The sample was then divided into quintiles from one (lowest) to five (highest). A single asset index was developed for the whole sample; indexes were not prepared for urban and rural populations.
>
> Fn 1:
> Variables include ownership of items listed in Table 2.9, except homestead; household characteristics in Table 2.8, except food consumption; and whether a household has at least one domestic worker.

## *Selected statistical output*

## Sequence of procedures

In partial analogy with the wealth index creation, I performed a principal components analysis on a set of 17 of the DHS-designated household wealth variables.  As the objective was to test a Rasch model, polytomous variables (4 of the 17) were dichotomized. In the line of Kolenikov et al. (op.cit.), I used polychoric PCA. For later item reduction, I regressed the DHA wealth index factor score (which had been normalized) and the polychoric PCA first component score on the 17 binaries. The results were visualized in the importance diagram on page 6.

The polychoric PCA confirmed a dominant first component. In the Rasch context, however, the unidimensionality of the item set can be tested through a Mokken scale procedure (Mokken 1971). Hardouin (2007a) gives the rationale; he wrote the STATA "msp" procedure, which I used; I also used STATA's generic "mokken", which produces a more didactic output telling the user "how good" his scale is.

Subsequently, I performed the Rasch analysis, calculating item difficulty parameters, score and the latent trait, using Hardouin's "raschtest". The quality of the Rasch scale as a suitable substitute for the (ordinary PCA-derived) DHS wealth index was evaluated by regressing the index on the latent trait (the subjects' ability variable). Because of omitted variables (I did not have the whole set used by DHS), dichotomization of some ordinal ones, and the non-linear (normalization) rescaling by DHS, I used a local regression procedure ("mrunning" in STATA; see Royston and Cox 2005).

Polychoric PCA, Rasch scale analysis, and regressions of the DHA wealth factor score on the Rasch latent trait were performed for 17-, 10 and 5-item sets. Mokken scale analysis was applied to the 17- and 10-item sets. The item reductions, however, were guided chiefly by the item frequencies (concern for regular spacing from rare to almost universal items) and by the effects of the items on the polychoric PCA first component score (concern for unidimensionality). I preferred polychoric PCA quantities to the Mokken scale statistics because the former accepted sample weights.

## Items and item dichotomization

```
              storage  display     value
variable name   type   format      label      variable label
-------------------------------------------------------------------------------
hv206           byte   %8.0g       hv206      has electricity

hv201           byte   %8.0g       hv201      source of drinking water
hv205           byte   %8.0g       hv205      type of toilet facility
hv215           byte   %8.0g       hv215      main roof material
hv214           byte   %8.0g       hv214      main wall material
sh31b           byte   %8.0g       sh31b      almirah (wardrobe)
sh31c           byte   %8.0g       sh31c      table
sh31d           byte   %8.0g       sh31d      chair/bench
sh31e           byte   %8.0g       sh31e      watch or clock
sh31f           byte   %8.0g       sh31f      cot or bed
hv207           byte   %8.0g       hv207      has radio
hv208           byte   %8.0g       hv208      has television
hv210           byte   %8.0g       hv210      has bicycle
hv211           byte   %8.0g       hv211      has motorcycle/scooter
sh31k           byte   %8.0g       sh31k      sewing machine
hv221           byte   %8.0g       hv221      has telephone
sh42            byte   %8.0g       sh42       owns any land
```

I also used, chiefly for descriptive purposes, the urban vs. rural variable and, for frequencies and polychoric PCA, the DHS-calculated sample weights. "raschtest" does not accept weights.

Four of the 17 indicators were polytomous, with implied partial ordinality. I created dichotomous variables:

```
goodwater       byte   %8.0g              Household has access to
                                          good water (based on hv201)
goodtoilet      byte   %8.0g              Household has good toilet
                                          (based on hv205)
goodroof        byte   %8.0g              Household dwelling has
                                          good roof (based on hv215)
goodwalls       byte   %8.0g              Household dwelling has
                                          good walls (based on hv214)
```

by recoding the superior variants as 1. For example,

```
                      | Household has access
                      | to good water
   source of drinking |
        water (hv201) |         0          1 |     Total
----------------------+----------------------+----------
piped inside dwelling |         0        667 |       667
piped outside dwellin |         0        222 |       222
             tubewell |         0      8,724 |     8,724
     shallow tubewell |         0         40 |        40
        deep tubewell |         0        469 |       469
surface well/other we |        96          0 |        96
       pond/tank/lake |       228          0 |       228
         river/stream |        52          0 |        52
                other |         1          0 |         1
----------------------+----------------------+----------
                Total |       377     10,122 |    10,499
```

## Polychoric PCA

Here I exemplify with the eigenvalues / proportion of variation explained as well as the scoring coefficients tables for the 17-item analysis (the STATA procedure name is "polychoricpca"):

```
Principal component analysis

 k  |  Eigenvalues  |  Proportion explained  |  Cum. explained
----+---------------+------------------------+------------------
  1 |    8.072373   |    0.474845            |   0.474845
  2 |    1.727664   |    0.101627            |   0.576473
  3 |    1.387052   |    0.081591            |   0.658064
  4 |    0.964059   |    0.056709            |   0.714773
[Output for subsequent component not shown here]
```

Instead of the scoring coefficients that the procedure routinely reports, a table of the (polyserial) correlation coefficients between the first three component scores and the items is more instructive. Coefficients greater than 0.50 are grayed.

| | **w17poly1** | **w17poly2** | **w17poly3** |
|---|---|---|---|
| hv206 | 0.74 | -0.35 | 0.12 |
| goodwater | 0.31 | -0.10 | 0.66 |
| goodtoilet | 0.69 | -0.35 | -0.16 |
| goodroof | 0.71 | -0.06 | 0.69 |
| goodwalls | 0.63 | -0.23 | 0.44 |

| | | | |
|---|---|---|---|
| sh31b | 0.81 | -0.13 | -0.17 |
| sh31c | 0.85 | 0.63 | 0.04 |
| sh31d | 0.86 | 0.61 | 0.04 |
| sh31e | 0.85 | 0.34 | -0.16 |
| sh31f | 0.84 | 0.58 | 0.57 |
| hv207 | 0.61 | 0.23 | -0.27 |
| hv208 | 0.86 | -0.26 | -0.09 |
| hv210 | 0.47 | 0.77 | 0.01 |
| hv211 | 0.83 | -0.18 | -0.53 |
| sh31k | 0.67 | -0.20 | -0.31 |
| hv221 | 0.92 | -0.55 | -0.37 |
| sh42 | 0.41 | 0.65 | -0.03 |

## Regression of the wealth index factor score on the 17 items

using DHS sample weights as analytic weights

```
      Source |       SS       df       MS              Number of obs =   10474
-------------+------------------------------           F( 17, 10456) = 2979.07
       Model |  7.1385e+13    17  4.1991e+12           Prob > F      =  0.0000
    Residual |  1.4738e+13 10456  1.4095e+09           R-squared     =  0.8289
-------------+------------------------------           Adj R-squared =  0.8286
       Total |  8.6124e+13 10473  8.2234e+09           Root MSE      =   37544

------------------------------------------------------------------------------
       hv271 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       hv206 |   34223.45   932.8695    36.69   0.000     32394.85    36052.05
   goodwater |  -9788.413   2198.143    -4.45   0.000    -14097.19   -5479.632
  goodtoilet |   49080.79   1003.552    48.91   0.000     47113.64    51047.94
    goodroof |  -2958.541   1415.441    -2.09   0.037    -5733.076   -184.0051
   goodwalls |   29355.22   828.6753    35.42   0.000     27730.86    30979.59
       sh31b |    23888.9   988.7181    24.16   0.000     21950.82    25826.97
       sh31c |   9686.583    1172.37     8.26   0.000     7388.513    11984.65
       sh31d |   9510.444   1180.642     8.06   0.000      7196.16    11824.73
       sh31e |   18666.26   965.3201    19.34   0.000     16774.04    20558.47
       sh31f |   6309.938   1450.328     4.35   0.000     3467.018    9152.859
       hv207 |   8151.408   879.5718     9.27   0.000     6427.279    9875.537
       hv208 |    45058.7   1138.455    39.58   0.000     42827.11    47290.29
       hv210 |   794.2746   921.3191     0.86   0.389    -1011.687    2600.236
       hv211 |   31079.53   2860.529    10.86   0.000     25472.35    36686.72
       sh31k |    36721.6   1721.776    21.33   0.000     33346.59    40096.61
       hv221 |   97608.97    1979.51    49.31   0.000     93728.75    101489.2
        sh42 |  -1377.319   781.2863    -1.76   0.078    -2908.789    154.1515
       _cons |  -97948.03   2500.287   -39.17   0.000    -102849.1   -93046.99
------------------------------------------------------------------------------
```

## Mokken scale analysis

For this step, I reproduce output for two item sets, the original 17, and then after the first reduction to 10. The motivation is to demonstrate the lack of unidimensionality in the 17 items, and the better quality of the 10-item scale. For its easier intuitive output, I use the output from STATA's generic "mokken" procedure, not from Hardouin's "msp":

## 17 items

```
Variable |  Obs    %Pos      Hi     z(H)    Label
```

```
---------+-----------------------------------------------------------------
hv211    |10499   0.023   0.649   50.576    has motorcycle/scooter
hv221    |10495   0.065   0.645   80.166    has telephone
sh31k    |10498   0.065   0.479   59.581    sewing machine
hv210    |10498   0.238   0.271   58.253    has bicycle
hv208    |10497   0.264   0.520  117.561    has television
goodtoile|10500   0.274   0.422   96.422    Houshold has good toilet (based
         |                                  on hv205)
sh31b    |10495   0.323   0.483  114.715    almirah (wardrobe)
hv207    |10498   0.324   0.355   84.278    has radio
hv206    |10498   0.445   0.442  105.812    has electricity
sh42     |10499   0.502   0.217   51.774    owns any land
goodwalls|10500   0.549   0.382   89.838    Household dwelling has good walls
         |                                  (based on hv214)
sh31c    |10497   0.636   0.550  122.467    table
sh31d    |10497   0.660   0.556  121.029    chair/bench
sh31e    |10494   0.686   0.558  116.797    watch or clock
goodroof |10500   0.915   0.522   63.103    Household dwelling has good roof
         |                                  (based on hv215)
sh31f    |10497   0.916   0.620   74.816    cot or bed
goodwater|10500   0.964   0.265   21.859    Household has access to good
         |                                  water (based on hv201)
---------+-----------------------------------------------------------------
Mokken H |                0.443  251.606

3 items have a scalability coefficient below the cutpoint 0.300
Consider dropping  hv210 sh42 goodwater

According to Mokken (1971:185), 0.40<=H<0.50 is a medium scale
```

## 10 items

```
Variable |  Obs    %Pos      Hi     z(H)    Label
---------+-----------------------------------------------------------------
hv211    |10499   0.023   0.756   43.878    has motorcycle/scooter
hv221    |10495   0.065   0.854   74.490    has telephone
hv208    |10497   0.264   0.647  106.630    has television
goodtoile|10500   0.274   0.539   90.128    Houshold has good toilet (based
         |                                  on hv205)
sh31b    |10495   0.323   0.578   99.026    almirah (wardrobe)
hv206    |10498   0.445   0.594  100.803    has electricity
goodwalls|10500   0.549   0.507   81.521    Household dwelling has good walls
         |                                  (based on hv214)
sh31e    |10494   0.686   0.618   85.362    watch or clock
goodroof |10500   0.915   0.587   53.191    Household dwelling has good roof
         |                                  (based on hv215)
sh31f    |10497   0.916   0.592   53.533    cot or bed
---------+-----------------------------------------------------------------
Mokken H |                0.595  180.543

According to Mokken (1971:185), H>=0.50 is a strong scale
```

## Rasch scale analysis

As with the Mokken scale analysis, the 17-item and 10-item output is given here:

## 17 items

At first, the item difficulty parameters were calculated:

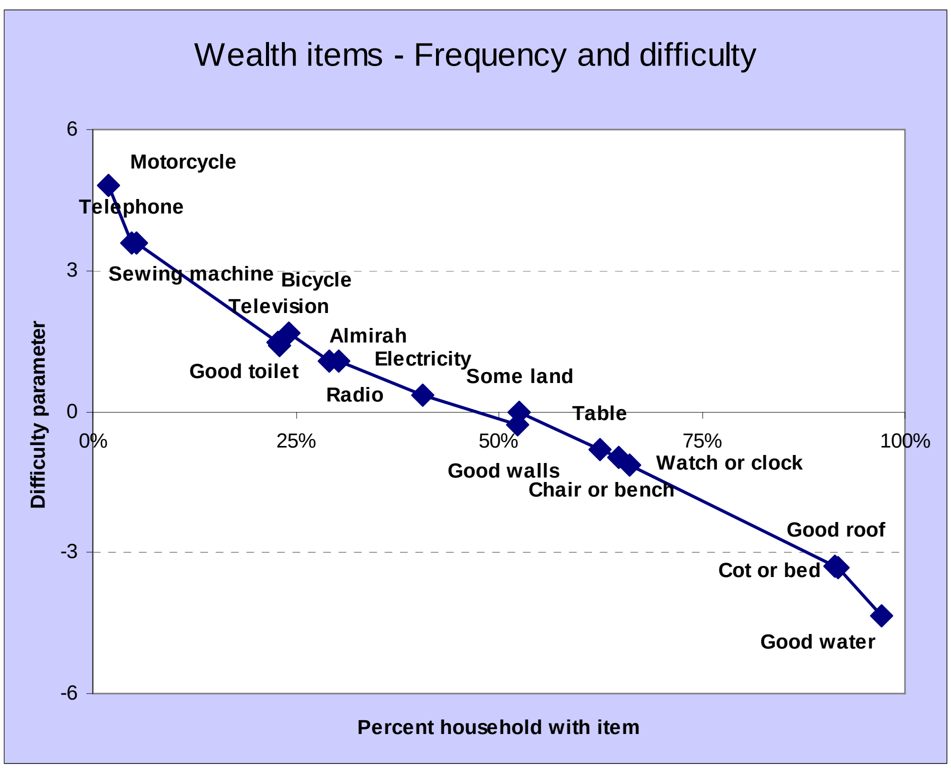
```
   Number of items: 17
   Number of groups: 18 (16 of them are used to compute the statistics of test)
   Number of individuals: 10437 (26 individuals removed for missing values)
```

| Items | Difficulty parameters | std Err. | Q1 | d.f. | p-value |
|---|---|---|---|---|---|
| hv206 | 0.33496 | 0.03350 | 94.845 | 15 | 0.00000 |
| goodwater | -4.35633 | 0.06364 | 643.561 | 15 | 0.00000 |
| goodtoilet | 1.40484 | 0.03534 | 143.508 | 15 | 0.00000 |
| goodroof | -3.30460 | 0.04807 | 33.659 | 15 | 0.00380 |
| goodwalls | -0.27661 | 0.03357 | 232.564 | 15 | 0.00000 |
| sh31b | 1.07416 | 0.03449 | 200.246 | 15 | 0.00000 |
| sh31c | -0.80990 | 0.03428 | 339.543 | 15 | 0.00000 |
| sh31d | -0.96661 | 0.03461 | 327.958 | 15 | 0.00000 |
| sh31e | -1.13475 | 0.03502 | 282.330 | 15 | 0.00000 |
| sh31f | -3.31068 | 0.04814 | 92.630 | 15 | 0.00000 |
| hv207 | 1.07047 | 0.03448 | 170.367 | 15 | 0.00000 |
| hv208 | 1.47127 | 0.03555 | 408.267 | 15 | 0.00000 |
| hv210 | 1.66139 | 0.03621 | 1219.257 | 15 | 0.00000 |
| hv211 | 4.80193 | 0.07504 | 89.727 | 15 | 0.00000 |
| sh31k | 3.57411 | 0.05102 | 30.620 | 15 | 0.00987 |
| hv221 | 3.57785 | 0.05107 | 315.220 | 15 | 0.00000 |
| * sh42 | 0.00000 | . | 2421.319 | 15 | 0.00000 |
| Van den Wollenberg test | | | 6631.175 | 240 | 0.00000 |
| Andersen LR test | | | Z1= 5345.482 | 240 | 0.00000 |

*: The difficulty parameter of this item had been fixed to 0

The following graph shows the relationship between item frequency and item difficulty. The relationship is nearly, but not perfectly, monotonic.

**Figure 2: Relationship between item prevalence and Rasch difficulty parameters**




Next, for each score (except the extremes) the corresponding latent trait value ("ability parameter") is calculated:

| Group | Score | Ability parameters | std Err. | Freq. | ll |
|---|---|---|---|---|---|
| 0 | 0 | | | 22 | |
| 1 | 1 | -4.58979 | 0.09577 | 154 | -143.8800 |
| 2 | 2 | -3.46174 | 0.04938 | 391 | -727.4900 |
| 3 | 3 | -2.59867 | 0.03425 | 669 | -1658.4676 |
| 4 | 4 | -1.88293 | 0.02760 | 854 | -2895.5703 |
| 5 | 5 | -1.28611 | 0.02586 | 822 | -3577.2727 |
| 6 | 6 | -0.77095 | 0.02287 | 929 | -4475.6793 |
| 7 | 7 | -0.30516 | 0.02021 | 1100 | -5503.4046 |
| 8 | 8 | 0.13334 | 0.02018 | 1057 | -5293.7825 |
| 9 | 9 | 0.56028 | 0.02060 | 1003 | -5093.3197 |
| 10 | 10 | 0.98918 | 0.02147 | 943 | -4677.0798 |
| 11 | 11 | 1.43504 | 0.02399 | 800 | -3676.5383 |
| 12 | 12 | 1.91753 | 0.02821 | 640 | -2700.1090 |
| 13 | 13 | 2.46380 | 0.03363 | 521 | -1919.8165 |
| 14 | 14 | 3.10915 | 0.04614 | 333 | -996.4988 |
| 15 | 15 | 3.90289 | 0.07512 | 159 | -414.7521 |
| 16 | 16 | 4.99471 | 0.15007 | 62 | -97.9978 |
| 17 | 17 | | | 15 | |

The loss at the extremes (household with no estimated latent trait) is relatively small for 17 items but increases for scales with fewer items.

## 10 items

```
Number of items: 10
Number of groups: 11 (9 of them are used to compute the statistics of test)
Number of individuals: 10168 (19 individuals removed for missing values)
```

| | Items | Difficulty parameters | std Err. | Q1 | d.f. | p-value |
|---|---|---|---|---|---|---|
| | hv206 | -4.33710 | 0.07357 | 40.009 | 8 | 0.00000 |
| | goodroof | -8.20506 | 0.08507 | 28.715 | 8 | 0.00036 |
| | goodwalls | -5.02108 | 0.07410 | 339.563 | 8 | 0.00000 |
| | goodtoilet | -3.04135 | 0.07308 | 99.517 | 8 | 0.00000 |
| | sh31b | -3.45475 | 0.07319 | 65.621 | 8 | 0.00000 |
| | sh31e | -5.93232 | 0.07541 | 69.460 | 8 | 0.00000 |
| | sh31f | -8.20986 | 0.08510 | 11.403 | 8 | 0.17990 |
| | hv208 | -2.95729 | 0.07306 | 191.453 | 8 | 0.00000 |
| | hv211 | 1.59056 | 0.10118 | 48.001 | 8 | 0.00000 |
| * | hv221 | 0.00000 | . | 43.463 | 8 | 0.00000 |
| | Van den Wollenberg test | | | 843.483 | 72 | 0.00000 |
| | Andersen LR test | | Z1= | 810.997 | 72 | 0.00000 |

*: The difficulty parameter of this item had been fixed to 0

| Group | Score | Ability parameters | std Err. | Freq. | ll |
|---|---|---|---|---|---|
| 0 | 0 | | | 194 | |
| 1 | 1 | -8.47735 | 0.05119 | 617 | -650.8844 |
| 2 | 2 | -7.06118 | 0.03080 | 1368 | -1618.9730 |
| 3 | 3 | -5.87994 | 0.02381 | 1867 | -3003.1370 |
| 4 | 4 | -4.91743 | 0.02217 | 1802 | -3622.9077 |
| 5 | 5 | -4.07302 | 0.02455 | 1358 | -3315.5773 |
| 6 | 6 | -3.24657 | 0.02833 | 1066 | -2495.5144 |
| 7 | 7 | -2.29909 | 0.03393 | 946 | -1760.9575 |
| 8 | 8 | -0.93381 | 0.04854 | 713 | -571.2878 |
| 9 | 9 | 0.93453 | 0.06909 | 431 | -210.9568 |
| 10 | 10 | | | 119 | |

by local regression of the DHS wealth factor score on the latent trait. To check what influence the loss of cases due to missing latent traits at the extremes of the Rasch score (household with zero or with all items present) had the association between the Rasch scale and the DHS index, I calculated also the rank order correlation between the index and the Rasch *score* (which is available for *all* cases with complete item information). The "spearman" procedure does not allow weights, though.

| Items in scale | Obs. w.. estimated Rasch latent trait | R-sq (on latent trait) (sample-weighted) | Spearman's (w. score) (unweighted) |
|---|---|---|---|
| 17 | 10,437 | 0.74 | 0.91 |
| 10 | 10,168 | 0.82 | 0.92 |
| 5 | 9,304 | 0.58 | 0.86 |

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## Acknowledgement

I am grateful for the access that the data archive staff at ORC Macro, a research firm conducting DHS, has given me to the Bangladesh survey data. However, any errors in using this data or interpreting its context are my own responsibility.

Professor Jean-Benoît Hardouin, Department of Biomathematics and Biostatistics, University of Nantes, Nantes, France is the author of the STATA procedures "msp" (Mokken scale analysis) and "raschtest", which I used in this study. He provided valuable technical advice and also made the thesis of Alessio Fusco (op.cit.) available.

## Author contact

abenini [ at ] starpower [ dot ] net

Draft 5 April 2007
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