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Research article

Comparison of weighted and unweighted methods of wealth indices for assessing SOCIO-ECONOMIC status

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ABSTRACT

Due to some of the limitations of monetary measures, various non-monetary approaches for assessing household wealth have been developed as alternative tools for classifying household socio-economic status. Among them, wealth indices based on household durable assets are being used. The literature revealed that two basic methods of constructing wealth indices are employed: an unweighted method, where assets are weighted equally; and a weighted method, where specific weights are assigned to assets. In the case of using the weighted method, weighting can be assigned using various techniques. The overall objective of the study is to compare the wealth indices constructed by using weighted and unweighted methods for assessing the socio-economic status of households in rural Bangladesh. Firstly, the study attempts to construct wealth indices based on durable assets using the unweighted method and two techniques of the weighted method: weighted index using the inverse of proportion, and weighted index using principal component analysis (PCA). Following this, the study compares some distributional characteristics of these indices as well as monetary indicators. At the same time, the study evaluates and examines some attractive properties of these indices such as the extent of clumping and truncation, consistency with traditional monetary measures. Comparative analysis revealed that the unweighted asset index, as well as weighted asset index using PCA, can be treated as an efficient alternative to the monetary measures to evaluate the living standard of the households in the present study. However, due to some advantage's asset index using PCA can be considered to be somewhat better than the unweighted index. But, as the unweighted asset index is not very different from the weighted asset index using PCA, it can also be used as an alternative to the monetary measures without the need to use weighting.

1. Introduction

Methods for assessing household socio-economic position or living standard can be categorized into two major types: monetary and non-monetary. The first category is customarily used by economists because it is easy to measure a household's socio-economic position with this standard. One of the main advantages of a monetary measure (i.e., income or expenditure) is the quantitative nature of the data, which both facilitates the establishment of varying levels within socio-economic positions as well as permits a breadth of quantitative analyses. The monetary measure is well understood by not only the experts but also the public. Its concept depends on the assumption that a person's material standard of living largely determines their well-being. Accordingly, the poor are defined as those who engage in a material standard of living measured by income and expenditure below a threshold–the poverty line (Falkingham and Namzie, 2001).

However, criticisms have been made overusing monetary measures to evaluate the household's socio-economic status in developing countries. In this concern, Sahn and Stifel (2003) explained five crucial problems of using household income or expenditure data as a proxy for classifying socio-economic positions in developing countries. First, the authors note the poor quality of income and expenditure data particularly in middle- and low-income countries. Secondly, measurement errors are inevitable due to income and expenditure data being based on recall memory. Thirdly, prices of goods, nominal interest rates, and depreciation rates for semi-durable or durable goods are difficult to discern when constructing

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consumption aggregates. Fourthly, consumer price indices in developing countries are often unavailable and unreliable. Lastly, regional and seasonal price indices in most developing countries are greatly variable and rare to find. Additionally, a monetary indicator does not take into account how money is earned and how much time is spent working. Furthermore, other practical issues raised in the monetary measures include sampling bias, under-reporting of income, difficulties of converting household products into money terms, etc.

Consequently, instead of using monetary indicators, other non-monetary approaches for assessing household welfare have been introduced and developed as an alternative tool for classifying household socio-economic status (Filmer and Pritchett 2001; Sahn and Stifel 2003; Oakes and Rossi 2003). As for non-monetary measures, researchers in the field developed various approaches such as the household asset index, the occupational status score (OSS), the Household Prestige (HHP) score, the capital SES (see for instance Krieger et al., 1997; Filmer and Pritchett, 1998). While monetary measures of poverty are developed by adjusting household members and thus measure poverty by member, the wealth index is developed as a characteristic of the total household. For example, Filmer and Pritchett (2001) state: "The asset index is not adjusted for household size because the benefits of many of the assets, such as quality of housing materials, the source of fuel, or lighting, are present at the household level."

Scholars at various academic and research institutes in different countries have years of experience using the asset index. Various studies explored several methods and analytical issues of asset-based indices. Filmer and Pritchett (2001) carried out an important study in this field. Filmer and Pritchett constructed an asset index by using principal component analysis (PCA). They found that the asset index was robust, produced internally consistent results, and provided a close correspondence with State Domestic Product (SDP) and poverty rate data. Unlike Filmer and Pritchett, Sahn and Stifel (2003) used factor analysis (FA) to construct weight for each asset instead of using PCA. Moreover, a seminal study was carried out on this concern by Prakongsai (2006). By using the PCA method, this study aims to explore the possibility of using the household asset index as either an alternative or a complementary measure to classify household socio-economic position, instead of using traditional monetary measures. In 2008 Howe et al. (2008) explored various issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries. In their study wealth indices were constructed by using the assets on which data are collected within Demographic and Health Surveys applying five weighting methods: PCA, PCA using dichotomized versions of categorical variables, equal weights, weights equal to the inverse of the proportion of households owning the item, and Multiple Correspondence Analysis. They mainly investigated the appropriateness of wealth indices as proxies for consumption expenditure. They found that the choice of data included had a greater influence on the wealth index than the method used to weight the data.

However, despite its use by many researchers, some criticisms have also been made against the use of the asset index. One criticism is that the components of the index are taken from a common list of commodities regardless of quality. Also, the asset index is usually a good proxy for permanent or long-term income, but it is a poor proxy for current household income or expenditure. The asset index is useful for relative analysis of welfare, but not for absolute levels of income or poverty (Prakongsai, 2006).

Although it has its limitations, the use of the asset-based indicator is supported by the researchers following many attractive features. Sahn and Stifel (2003) described three advantages. First, in comparison with household income and expenditure, household assets are fewer and easier to measure. Second, the accuracy and validity of asset data are usually better than that of income or expenditure data. Finally, the asset data are less likely to have reporting bias and through a simple checklist, are validly assessed by interviewers. Also, like monetary measures, the asset index provides a quantitative proxy for household welfare. Thus, due to its features as well as the difficulties in obtaining comprehensive data of household income and expenditure, the asset index is increasingly chosen by researchers to evaluate households' living standards over traditional monetary measures.

Researchers suggested that the wealth index using PCA is a reasonable response to data when household wealth cannot be measured directly (Zimmer, 2008). In South Asian communities, simple household assets data, collected under field conditions, are suggested for use in constructing a reliable and useful wealth index by PCA. Such an index can assist in the assessment of health, quality of life, and inequalities in health (Gunnsteinsson et al., 2010; Halder and Kabir, 2008; Yanagisawa et al., 2012). Hoque (2014) applied two distinct methods, PCA and fuzzy set theory (FST) to household survey data from rural Bangladesh. The study findings show that both PCA and FST can lead to reliable results in terms of poverty analysis. Different authors suggest various methods and techniques construct asset indices (for example, see Moser and Felton, 2007).

The literature revealed that no study has been conducted in the context of rural Bangladesh that compares the various methods (more than two) of wealth index. Few studies, in general, compare various methods of constructing wealth indices. Among these rare studies, Howe et al. (2008) compared five methods. Falkingham and Namzie (2001) provided a comparative discussion on various methods without empirical analysis. Rahman et al. (2013) provided three methods without comparison. On the other hand, Filmer and Pritchett (2001), Prakongsai (2006), McKenzie (2003), Vyas and Kumaranayake (2006) Gunnsteinsson et al. (2010) and many others only report on the PCA method alone. Therefore, the present study may open a horizon of research that aims to answer the question: is PCA the best method or can any other easier method provide better or at least similar results? In the context of Bangladesh, such a comparison of three wealth indices is a new addition to the literature.

The overall objective of the study is to compare the wealth indices constructed by using weighted and unweighted methods for assessing the socio-economic status of households in rural Bangladesh. The specific objectives are:

- To construct wealth indices based on household durable assets by using the unweighted method and two techniques of weighted method
- To compare some distributional characteristics of these indices as well as of traditional monetary indicators
- To assess the extent of clumping and truncation of these indices using graphical presentations
- To measure the consistency of these indices with monetary indicators numerically and graphically.

Only household durable assets are considered in the present study. Possession of household durable assets promotes mobility and increases the comfort of the household members and thus eases the livelihood and enhances the welfare of households. Rahman et al. (2009) defined household durable assets as those that usually include different household items, luxury items, tools, transportation, etc. Following some previous studies like Rahman et al. (2009), and Rahman et al. (2013) several durable assets were considered that contain various types. The issues that are viewed in mind are: according to the definition of Rahman et al. (2009), the inclusion of all types of durable assets; the context of rural Bangladesh; and following similar studies.

The remainder of this paper is organized as follows. Section 2 presents the method, sampling procedure, and data used in the study. Section 3 discusses the empirical results and findings. Section 4 concludes the paper.

2. Methodology

This section describes the materials and methods used in the study. It discusses the methods of constructing the wealth indices, the sampling procedure, the selection of durable assets, and the analytical techniques.

2.1. Methods of constructing wealth indices

In the present study, three methods of constructing asset-based indices have been used. These are the unweighted asset index, the weighted asset index using the inverse of proportion, and the weighted asset index using Principal Component Analysis (PCA). For convenience, the indices are named index 1, index 2, and index 3 respectively. Among others, Filmer and Pritchett (2001), McKenzie (2003), Prakongsai (2006), Vyas and Kumaranayake (2006), Howe et al. (2008), Zerin (2009), Rahman et al. (2013) have developed and applied several methods for constructing asset-based indices to measure the level of asset ownership of households and to classify their socioeconomic positions. In light of those studies, the aforementioned methods of constructing asset indices are described.

2.1.1. Unweighted asset index (Index 1)

This is the easiest method, which involves simply summing up the number of assets possessed by a household. This method is often called the index using equal weight. The unweighted asset index is widely used in the literature (See, for example, Ucar, 2015; Zerin, 2009; Howe et al., 2008; Bhuiya et al., 2007).

Suppose there are n households selected as the sample for the study. Let there be k types of assets considered in the study that a household may possess.

Let,

$X_{ij} = 1$; if jth household possesses ith type of asset where i = 1, 2……k and j = 1,2,……n
=0; if jth household does not possess that asset.

Using the unweighted method, the asset index of jth household is given by

$$A_{1j} = \sum_{i=1}^{k} X_{ij};\ j = 1, 2, 3\ldots\ldots\ldots\ldots n \tag{1}$$

2.1.2. Weighted asset index using the inverse of proportion (Index 2)

This index uses the inverse of the proportion of households that own a certain asset to weight that asset's value in the index, originally suggested by Townsend (1979). This method, also used by researchers including Howe et al. (2008). The underlying assumption is that assets owned by a smaller proportion of households are indicative of higher wealth and hence are assigned with a higher weight. Using this method, the asset index of jth household is given by

$$A_{2j} = \sum_{i=1}^{k} \left(\frac{f_i}{n}\right)^{-1} X_{ij} \quad , j = 1, 2\ldots\ldots\ldots\ldots n \tag{2}$$

where, f_i is the frequency of ith type of asset.

2.1.3. Weighted asset index using principal component analysis (Index 3)

In this study, Index 3 applies weights derived from principal component analysis (PCA) about Filmer and Pritchett (2001). The study of Filmer and Pritchett (2001) is considered to be the pioneer in this field, explaining in detail how a wealth index can be constructed by using the PCA method. Nowadays it is an established method for constructing wealth indices and is widely used in several studies (See, for instance, Prakongsai (2006), Vyas and Kumaranayake (2006), Gunnsteinsson et al. (2010)). The crucial assumption in the Filmer and Pritchett (2001) study is that a household's long-run wealth explains the maximum variance (and covariance) in the asset variables.

Theoretically, PCA is a statistical technique that uses an orthogonal transformation to convert a set of correlated variables into a set of linearly uncorrelated variables called principal components. This transformation is defined in such a way that the first principal component contains the highest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component, in turn, has the highest variance possible under the constraint of orthogonality to (i.e., uncorrelated with) the preceding components (Johnson and Wichern, 2002).

PCA can determine the weight as a factor score for each asset variable considered in the study. For constructing a wealth index, the first principal component is used to represent the household's living standard. The weights for each variable from this first principal component are used to generate a household score. As perceived from the basic concept of PCA, the first principal component is the linear index of variables having the largest amount of information common to all of the variables.

The asset index derived from PCA for jth household is given by

$$A_{3j} = \sum_{i=1}^{k} S_i\left(\frac{X_{ij} - \overline{X}_i}{\sigma_i}\right), \quad j = 1, 2\ldots\ldots\ldots\ldots n \tag{3}$$

where, S_i= Scoring factor for ith asset.

$\overline{X}_i$ = Mean of ith asset
σ_i = Standard deviation of ith asset

2.2. Sampling procedure

In this study, a two-stage sampling design has been used, where the Primary Sampling Units (PSUs) are designated as villages, while the Secondary Sampling Units (SSUs) comprise households within the village.

In the first stage, 20 PSUs (villages) have been selected from the list of all villages in Bangladesh following the standard systematic probability proportional to size (PPS) sampling method. A village wise household list was used from the Population and Housing Census 2011 (BBS, 2012) to apply the PPS method. While conducting PPS, all villages of the whole of Bangladesh were arranged geographically from the starting of the north to the end of the south, irrespective of the division, district, or other administrative units or any other criteria. It is noted that this study intends to provide the results, in general, in overall areas of rural Bangladesh.

From each of the selected villages, 18 households have been selected randomly in a systematic fashion. Thus, a sample of 20 × 18 = 360 households has been selected for the study. In each of the selected villages, a listing operation was conducted to prepare an up-to-date sampling frame. Then from the list, 18 households have been selected randomly in a systematic fashion. While selecting households, types of livelihood or any other criteria were not set. Because it would lead to a loss of generality. Also, in this study, we want to investigate the agreement of asset indices with income and expenditure not with their type of livelihood or any other criteria. It is noted that asset ownership may vary with the type of livelihood, but it happens because income and expenditure vary with the type of livelihood. Therefore, data on asset ownership and income-expenditure can adequately meet the objective of the study.

The whole of Bangladesh has been considered as the total study area. A map of Bangladesh showing the study area and sample locations is given below (Figure 1).

The study was conducted for three months, started on 1st September 2013 and ended on 30th November 2013. The data were collected using face-to-face interviews. To collect primary data, a well-designed questionnaire was prepared for this study. Taking in mind the difficulties in collecting monetary indicators, data on household income and expenditure were collected technically and carefully. Data on household income were collected in the following ways:

- Income comes out from different occupations of main earning members of the households;

Figure 1. A detailed map of the sample area, showing sample locations.

- Income from different occupations of secondary earning members in the households if any;
- Income from many other sources excluding the above two ones. It may include agriculture (crops/vegetables/trees/fruits), poultry, livestock, fishing, fishery, irregular business or handicraft, rent of house/shop, labor, scholarship, donation, allowance, private tuition, Vulnerable Group Development (VGD)/Vulnerable Group Feeding (VGF) card, etc.

On the other hand, since expenditure can usually be measured with relatively fewer difficulties in socio-economic surveys, data on expenditure were collected with comparatively fewer break downs. Thus, data on household expenditure were collected broadly in four sources: food, health/treatment, education, and others (cloths, transportation, donation, etc.). Accordingly, in the household income and expenditure sections of the questionnaire, respondents were requested to mention their incomes from all available sources and expenditures in different sectors. All amounts of income from various sources were summed up to get a total monthly income. Similarly, all expenditures in different sectors were summed up to get total monthly expenditures. Separate questions for various possible sources of income and expenditure are expected to decrease the chance of error in this regard. Similar instances for collecting income and expenditure data in this way were cited in many works of literature such as (Rahman, 2005; Rahman et al., 2009).

The proper restrictions were maintained during the data processing and data analysis stage. The database was developed by dropping some key identifiers of each household, prohibiting inadvertently revealing the identity of a respondent. The sample size for this study is small compared

Table 1. Distribution of households by background characteristics.

Background characteristics	Frequency	Percent (%)
Household size		
2–3 members	50	13.889
4 - 5 members	202	56.111
6 - 7 members	71	19.722
8 and above	37	10.278
Monthly income of the household		
Tk. 1 - 5000	24	6.677
Tk. 5001 to 10000	204	56.677
Tk. 10001 to 15000	72	20.000
Tk. 15001 to 20000	35	9.722
Above Tk. 20000	25	6.944
Monthly expenditure of the household		
Tk. 0 - 5000	33	9.167
Tk. 5001 to 10000	232	64.444
Tk. 10001 to 15000	64	17.778
Above Tk. 15000	31	8.611
Durable assets owned by households		
Furniture		
Almira	157	43.611
Wardrobe/Cabinet	47	13.056
Showcase	199	55.278
Dressing table	55	15.278
Sofa	11	3.056
Table	266	73.889
Chair/Bench	284	78.889
Meat safe	94	26.111
Bed/Cot	352	97.778
Electrical & electronic items or home appliance		
Mobile/Telephone	283	78.611
Electric fan	187	51.944
Watch	110	30.556
TV	127	35.278
Refrigerator	25	6.944
CD/VCD player	19	5.278
Computer/Laptop	5	1.389
Ornaments		
Silver Ornament	236	65.556
Gold Ornament	298	88.778
Transportation		
Bicycle	75	20.833
Motorcycle	17	4.722

Source: Field Survey, note: Permitting respondents to list more than one asset caused frequencies and percentages to exceed 100%. Almirah (a piece of furniture for hanging clothes); Showcase (a cupboard, which front side is made of transparent glass to show someone or something in a way that attracts attention); Meat safe (a ventilated cupboard for securing provisions from pests).

to the total population of the country, this is, due to the cost and time constraints. However, the study design and sampling design as mentioned above are technically sound, and the sample is geographically spread over the country since the standard systematic PPS design has been used keeping the PSUs (villages) arranged geographically. It is noted that, after applying the aforementioned method of sampling, it is interestingly found that more than one PSU (village) has not come from the same district. Thus, in reality, 20 villages have been selected from 20 districts. Thus, the sample is not clustered in some regions, rather it covers the whole country. Furthermore, considering we already know that rural communities in Bangladesh are more or less homogenous in respect of socioeconomic characteristics. Thus, the sample so obtained can meet the required level of representativeness for the study population. Notably, the concept and findings of this study may create scope for further similar studies with larger samples at the government level, which potentially could discover the most appropriate proxy measure for assessing socioeconomic status.

2.3. Selection of household durable assets

According to the objectives, the main focus of this study is to construct different types of wealth indices as proxy measures for classifying household socio-economic status. "A proxy is an indirect measure of the desired outcome which is itself strongly correlated to that outcome. It is commonly used when direct measures of the outcome are unobservable and/or unavailable" (GovEx, 2017). To assess household socio-economic status monetary indicators can be used for the direct measure while different types of asset variables may be used for indirect measure. The study attempts to construct wealth indices based on household durable assets.

Twenty types of durable assets have been considered in the study. A wide range of asset variables should reasonably be included when constructing a wealth index. To avoid problems like clumping and truncation, Vyas and Kumaranayake (2006) suggested adding more asset variables that capture inequality between households. Also, the assets have been chosen based on rural perspectives of the country. Therefore, items like air conditioners, washing machines, ovens, etc. have not been included. Bhuiya et al. (2007) considered only six durable assets in this regard while fourteen assets were kept into account in the study of Zerin (2009). In the study of Prakongsai (2006) a range of 28–30 types of household assets and household characteristics from a series of household survey data in Thailand were included that could be classified into three groups: housing characteristics, types of household sanitation, and water supply and, ownership of durable and semi-durable assets.

In the current study, durable assets include furniture, electrical and electronic items or home appliances, ornaments, and transportation tools. The information has been collected on the possession of a total of the 20 household durable assets, which include 9 furniture items, 7 electrical and electronic devices, 2 ornamental items, and 2 transportation items. The household durable assets that have been included in the study are listed in detailed Table 1. This study does not claim that this number and type of assets are the most appropriate for constructing a wealth index. Determining the appropriate number of assets and the types of assets in the context of rural Bangladesh is undoubtedly an interesting study topic, but it is not the purpose of this study.

Some other studies such as McKenzie (2003), Vyas and Kumaranayake (2006) and Howe et al. (2008) also used assets other than durable ones to construct wealth indices. It is quite laborious and time-consuming to obtain data on a lot of various types of assets. We believe our methods provide an adequate proxy measure, using a limited number of assets with less effort. Information on ownership of chairs, tables, or TVs can be collected with less effort as compared to ownership of land, amount of land, type of drinking water, etc. Also, one of the main reasons for using the proxy measure is to avoid difficulties associated with obtaining monetary data. However, if we were to bear the extra load of obtaining more data using alternative methods, the purpose of the alternative proxy could be called into question, as in such a case, we are doing away with one form of complexity for another. Upon the circumstances, the present study considered only durable assets, deliberately avoiding considering many other assets to limit unnecessary complexities.

2.4. Analytical techniques

For the analytical purpose of the wealth indices as proxy measures, different analytical techniques are cited in the literature, such as Pearson's product-moment correlation, scatter plots, Spearman's rank correlation, use of Kappa statistic, classification in different quantiles (e. g. tercile, quintile), graphical representation, etc. For example, Ucar (2015) and Prakongsai (2006) conducted Pearson's correlations between the asset index and household income and household expenditure, and Howe et al. (2008) used classification in quintiles and a graphical representation, and Kappa statistic, while Filmer and Pritchett (2001) performed rank correlation and classification in terciles. Zerin (2009) and Bhuiya et al. (2007) used the scatter plot along with other methods. The literature revealed that no study applied all the analytical methods. Following past studies, we performed graphical representation, Pearson's correlation analysis, and scatter plots, and also, we conducted a comparative analysis of descriptive statistics.

3. Results and discussions

In Table 1, we provide descriptive statistics for each of the households used in the study. The descriptive statistics display the frequency and percentage distribution of household size, monthly income and expenditure, and household durable assets by household category. For an additional description of some assets, see notes at the end of Table 1. Using Eqs. (1), (2), and (3) the indices based on the above twenty durable assets have been constructed. As per this study's objectives, adequate analyses have been conducted to produce the necessary results and graphs. All findings are accompanied by necessary discussions and are presented below.

3.1. Distributional characteristics of asset indices and monetary indicators

As the asset index is used as an alternative measure of a household socioeconomic position to monetary measures (income or expenditure), it is logical that similarity should exist in the distributional characteristics of the asset index with household income and expenditure measures particularly in the case of shape characteristics. Because, if for example, income distribution is symmetric but the asset index is highly skewed, and/or income distribution is mesokurtic but the asset index is leptokurtic, then the classification of households' socio-economic position is based on this index will certainly mismatch with the classification based on income distribution. Accordingly, Table 2 displays a comparative scenario of distributional characteristics of these three indices along with household income and expenditure.

Table 2 shows that, in terms of relative measures of variation, index 1 (unweighted assets index) displays a higher level of similarity with income and expenditure than the other two indices. Here, index 3 (weighted asset index using PCA) shows very high variation. It is concordant with the feature of principal component analysis, as it accounts for maximum variation in the data. On the other hand, regarding shape characteristics, index 1 and index 3 are more or less alike and compared to index 2 they do not differ much from income and expenditure. In contrast, the skewness and the kurtosis of index 2 are exceptionally high when compared to the other two indices, as well as in comparison to household income and expenditure. That is, the shape characteristic of index 2 is very different from that of the other two indices as well as from income and expenditure. Thus, particularly in respect of shape characteristics, index 2 is the worst in capturing income

Table 2. Distributional characteristics of asset indices and household income and expenditure.

Different measurements of the distribution	Unweighted asset index (Index 1)	Weighted asset index using the inverse of proportion (Index 2)	Weighted asset index using PCA (Index 3)	Monthly household income	Monthly household expenditure
Mean	7.908	20.000	-0.134	10523.470	9255.083
Median	8.000	13.625	-0.275	8940.417	8250.000
Mode	8.000	2.231	-1.664	9200.000	7700.000
Std. Deviation	3.602	21.503	1.121	5424.326	4161.862
CV	0.455	1.075	8.346	0.515	0.450
Skewness	0.234	2.818	0.824	1.624	1.622
Kurtosis	-0.431	9.592	0.562	2.875	3.880
Minimum	1.000	1.023	-2.079	1725.000	1000.000
Maximum	19.000	142.283	3.765	33000.000	30000.000

Note: Multiple modes exist. The smallest value is shown.

and expenditure distributions while index 1 and index 3 are almost similar.

3.2. Graphical presentations of asset indices

A major challenge for asset-based indices is to avoid the problems of 'clumping' and 'truncation' (McKenzie, 2003). Clumping or clustering is described as households being grouped into a small number of distinct clusters (Wilunda et al., 2013; Vyas and Kumaranayake, 2006). On the other hand, truncation implies a more even distribution of socio-economic status, but spread over a narrow range, making it difficult to differentiate between socio-economic groups (Vyas and Kumaranayake, 2006). Both the issues of clumping and truncation result in difficulties in differentiating households between socio-economic groups (Wilunda et al., 2013). Therefore, the asset index is expected to be free from these two problems.

The graphical presentation is a useful tool to examine the existence of clumping and truncation. For example, in the study of Howe et al. (2008), the authors constructed five types of asset indices, and the distribution of each index was examined graphically. They found severe clumping in four of the five indices constructed in their study. Vyas and Kumaranayake (2006) also constructed asset indices for urban and rural areas of Brazil and Ethiopia in their study. By graphical presentations, they observed that the index for rural Ethiopia had both the problems of clumping and truncation. For the present study let us observe the graphical presentations of the distribution of asset indices to examine the extent of clumping and truncation.

Graphical presentations of each of the three indices reveal that the distribution of index 2 (Figure 2 (b)) is quite dissimilar with that of index 1 (Figure 2 (a)) and index 3 (Figure 2 (c)). Unlike index 2, the distribution of index 1 and index 3 is almost symmetric. Also, it is encouraging to observe that index 1 and index 3 are free from the problems of clumping and truncation as evident from the graphical presentation. This may be due to fact that the range of asset variables included in the present study is broad enough to avoid problems of clumping and truncation since a suggested method that could solve this issue is to add more asset variables that capture inequality between households (Vyas and Kumaranayake, 2006). In the distribution of Index 2 however, both the problems of clumping and truncation are apparent. Thus, in this respect, index 2 is not likely to be as good a measure as index 1 and index 3, for the socio-economic status of the households in the study.

Graphical presentations of the distributions of these three indices are given below.

3.3. Correlation analyses of asset indices with household income and expenditure

After the construction of asset indices, researchers often compare the various types of indices and assess the association of the indices with monetary measures. The stronger the association between them, the more the index works as an efficient alternative to monetary measures. Table 3 shows the correlations of three indices with household income and household expenditure along with p-values for significance tests. Correlation analysis shows a good agreement and consistency of the asset indices with money-metric measures as the correlations are fairly stronger compared to other similar studies. Prakongsai (2006) constructed asset indices for three years and found a moderate correlation between the asset indices and household income/expenditure, ranging from 0.52 to 0.54. Filmer and Pritchett (2001) found the Spearman rank correlations across households ranging from 0.43 to 0.64 in three countries. Also, Ucar (2015) conducted Pearson's correlation coefficient analyses among the asset index and monetary indicators and found that it was 0.64 between asset index and expenditure and 0.63 between asset index and income. Moreover, Ucar (2015) treated such correlation values

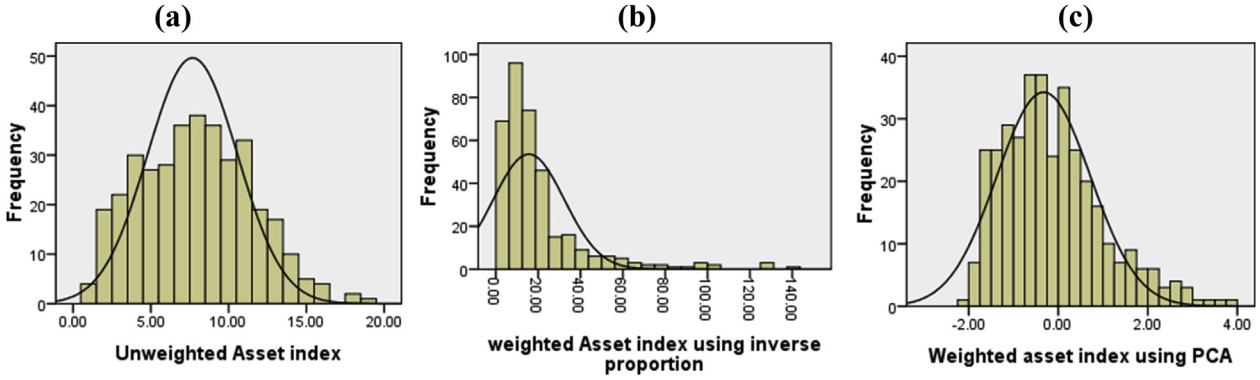

Figure 2. (a) The distribution of asset index using the unweighted method in the first panel; (b) The distribution of asset index using the inverse of proportion; (c) the distribution of asset index using PCA.

Table 3. Pearson Correlations of asset indices and household income and expenditure.

Indicators	Unweighted asset index (Index 1)	Weighted asset index using the inverse of proportion (Index 2)	Weighted asset index using PCA (Index 3)	Monthly household income	Monthly household expenditure
Unweighted asset index (Index 1)	1.000	0.788 ***	0.972 ***	0.648 ***	0.610***
Weighted asset index using an inverse of proportion (Index 2)	0.788***	1.000	0.839 ***	0.595 ***	0.555***
Weighted asset index using PCA (Index 3)	0.972 ***	0.839 ***	1.000	0.664***	0.622 ***
Monthly household income	0.648 ***	0.595 ***	0.664 ***	1.000	0.924 ***
Monthly household expenditure	0.610 ***	0.555 ***	0.622 ***	0.924***	1.000

Note: Correlations are tested at 0.01 level of significance (2-tailed). *** indicates that the coefficient is significant at 1% level of significance.

as "quite high". Whereas, in our study, we got the correlation ranging from 0 .555 to 0 .664. Particularly in index 1 and index 3, the values of the correlations range from 0.610 to 0.664.

However, comparing among three indices, index 2 has the lowest correlations with income and expenditure indicating its lowest association with monetary indicators. Therefore, in terms of correlation analysis, Index 1 and index 3 can be regarded as quite consistent with money-metric measures while index 2 is comparatively less consistent.

Also, higher correlation values among the indices indicate their common ability to perform as proxy measures. Particularly, a very high correlation (r = 0.972) between index 1 and index 3 indicates their high similarity in their efficiency.

Scatter plots of each of the three indices with household income and expenditure are displayed in Figures 3, 4, 5, 6, 7 and 8 below.

Figure 3. Scatter plot of the unweighted asset index (Index 1) and household income.

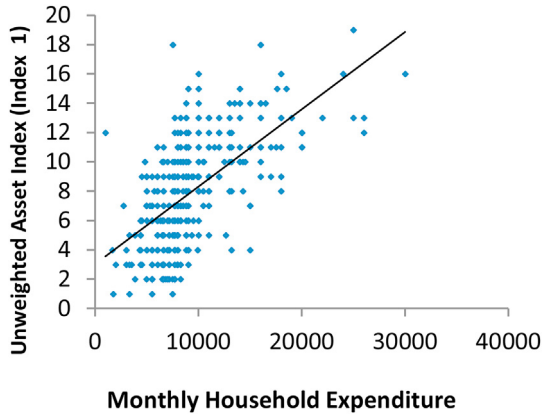

Figure 4. Scatter plot of the unweighted asset index (Index 1) and household expenditure.

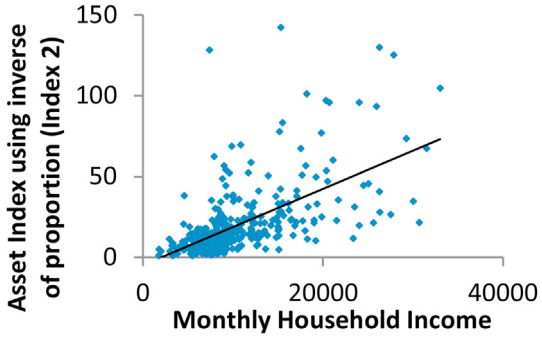

Figure 5. Scatter plot of the asset index using (inverse of proportion) (Index 2) and household income.

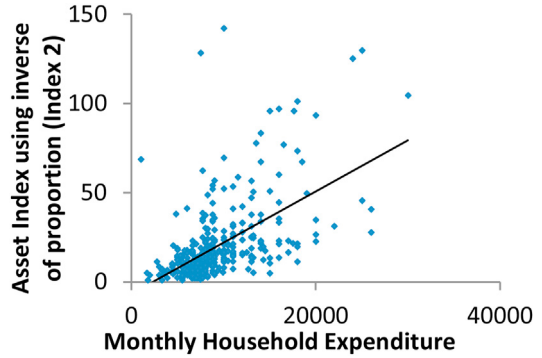

Figure 6. Scatter plot of the asset index using (inverse of proportion) (Index 2) and household expenditure.

Figure 7. Scatter plot of the asset index using PCA (Index 3) and household income.

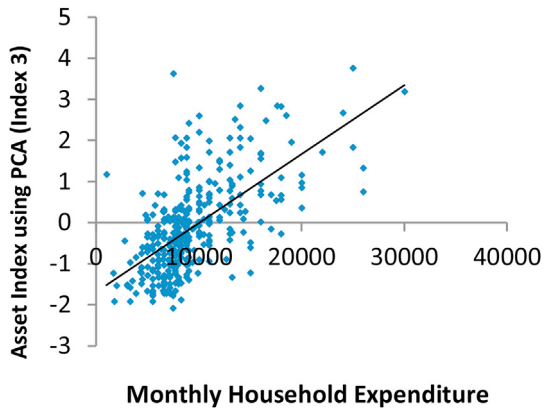

Figure 8. Scatter plot of the asset index using PCA (Index 3) and household expenditure.

As apparent from results and discussions, in all aspects of analysis, index 2 cannot perform well as a proxy measure for assessing socioeconomic status. It may be due to the limitations in its weighting procedure. Despite being a potentially simple and easily understood method, index 2 has some serious drawbacks. Because, under the assumption of this method, assets owned by a smaller proportion of households (i.e. rare items) are indicative of higher wealth and hence are assigned higher weights. This assumption may not be true for some items that are rare, not due to being costly or precious but due to some other reasons such as reduced application, availability of better alternatives, etc. For example, now a day's plough and radio are often rare items in Bangladesh due to reduced application as their alternatives are available. Another drawback is that there may be some assets that do not show a linear relationship with economic status. For example, ownership of a bicycle may tend to increase up to a certain level of income and subsequently decrease in wealthier households.

In contrast, in light of findings obtained from different analytical approaches, it is evident that index 1 and index 3 perform quite well as proxy measures. However, the unweighted asset index has the drawback of assigning equal weight to ownership of each asset. This is often unrealistic; because this method, for example, would assign equivalent worth to own a TV, refrigerator, table, and chair although, in reality, their contributions to the asset variable are certainly dissimilar. Nevertheless, the great virtue of this index is its simplicity.

Similarly, index 3 has also some limitations. The basic limitation of this method is that PCA is designed for continuous and normally distributed data. Therefore its application to the discrete data in a wealth index is not appropriate. Also, this index is constructed based on the first principal components that frequently explain only a low proportion of the total variation in asset data. Also, this method is fairly complex and poorly understood by less technical readers (Howe et al., 2008). But, from the theoretical aspect weighted asset index by using PCA has some interesting features. In this method, a weight is assigned to each variable (asset) to maximize variation of a new variable, subject to several constraints and the weight of each asset divided by its standard deviation has an interesting interpretation (Prakongsai, 2006). Through this interpretation, the household items can be ranked which provides relative importance of them in socio-economic evaluation. Therefore, through index 3 one can get some additional results (relative importance) while using index 1 one can enjoy its simplicity.

4. Conclusion

As evident from correlation analysis and graphical presentation as well as distributional characteristics presented above, unweighted as well as weighted asset indices using PCA are better alternatives to the monetary measures to assess the household living standard in the study while weighted asset index using the inverse of proportion does not work well as an alternative to income or expenditure. Findings reveal that unweighted and weighted asset indices using PCA have almost similar efficiency as proxy measures. However, in respect of attractive theoretical features, the weighted index by using PCA can be treated as a somewhat better option than the unweighted index. Nevertheless, since the unweighted index has almost similar characteristics as the weighted index by using PCA does and it has the advantage of simplicity, it can also be used. That is, by using an unweighted asset index one can assess the socio-economic status of households with enough accuracy without bothering with weights. It is noted that a common limitation of all three methods of wealth indices used in this study is that they capture only the ownership of assets and ignore their quality and quantity. So, there is a great scope for further research to develop some methods that can take into account of quality and quantity of the assets and can examine their contribution while constructing wealth indices as proxy measures.

Declarations

Author contribution statement

Muhammad Tareq: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Assim Ibrahim Abdel-Razzaq: Performed the experiments; Wrote the paper.

Md Rahman: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Tonmoy Choudhury: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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