The wealth index as a measure of socio-economic position

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I declare that the work presented in this thesis is my own

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Abstract

Background

The wealth index is a commonly-used measure of socio-economic position (SEP) in low- and middle-income countries. The approach arose from Demographic and Health Surveys (DHS) where few other options for SEP-measurement are available. Despite many unanswered questions the wealth index approach, and the methods of wealth index construction used by the DHS, have been widely-adopted by the epidemiological community. This thesis explores the appropriateness of the wealth index as a measure of SEP, using data from the Malawi Integrated Household Survey 2004/5 (IHS2) and Brazil DHS 1996.

Main findings

1) The wealth index and consumption expenditure

Some proponents of the wealth index claim it to be a reliable and rational proxy for consumption expenditure; a systematic review of the literature demonstrated this to be an unreasonable assumption. Analyses of IHS2 data showed that the agreement of the wealth index with consumption expenditure is largely unaffected by alternative equivalence scales for adjusting consumption expenditure for household size and composition, or by the range of items included in the consumption expenditure aggregate.

2) Are the methods of wealth index construction used by the DHS the most appropriate?

The DHS use principal components analysis (PCA) to weight the indicators in a wealth index; issues in the use of PCA were considered and alternative weighting methods explored. When nominal or ordered categorical indicators are used, alternatives to PCA are considered preferable. A single wealth index is often constructed for urban and rural areas together; generating separate indices for each area had little effect on the final index. Agreement with consumption expenditure was lower in rural areas; various approaches to wealth index construction did not alter this. Expanding the range and number of indicators used by DHS wealth indices did not increase agreement with consumption expenditure, but it did reduce

the observed urban-rural differences and enhance the ability of the wealth index to differentiate between rural households.

3) What socio-economic processes contribute to the wealth index hierarchy?

A key issue for any measure of SEP is its conceptual clarity; analyses of the IHS2 data demonstrate that the socio-economic processes leading to a wealth index hierarchy remain largely unknown, although both household- and community-level factors play a role.

4) Alternatives to the wealth index

Potential alternatives to the wealth index were explored, and the consequences of using the wealth index versus these alternatives were assessed for different purposes. The uncertainty about the socio-economic processes being captured by the wealth index implies that in all situations, the wealth index should only be used after careful consideration of available alternative SEP indicators.

Conclusions

Using the wealth index in the DHS has allowed the quantification and comparison of health inequalities in low- and middle-income countries on an unprecedented scale, thereby playing a vital role in advocacy of health equity. Some alterations to the methodology of wealth index construction are recommended for future studies using the wealth index, but the use of the wealth index in primary data collection is questionable given the uncertainty surrounding the socio-economic processes it is capturing.

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Glossary of terms and abbreviations

CFI	Comparative Fit Index
CI	Confidence Interval
DHS	Demographic and Health Survey
EA	(Census) Enumeration Area
EPC	Expected parameter change
ELQ	Economic Ladder Question
FA	Factor Analysis
GDP (PPP)	Gross Domestic Product (Purchasing Power Parity)
GEE	Generalised Estimating Equations
HAZ	Height-for-age z-scores
IHS2	(Malawi) Integrated Household Survey 2
LRT	Likelihood Ratio Test
LSMS	Living Standards Measurement Survey
MCA	Multiple Correspondence Analysis
MI	Multiple Imputation
MICS	Multiple Indicator Cluster Survey
NGO	Non-governmental organisation
OR	Odds Ratio
PCA	Principal Components Analysis
PSU	Primary Sampling Unit
RII	Relative Index of Inequality
RMSEA	Root mean square error of approximation
SE	Standard error
SEM	Structural Equation Modelling
SEP	Socio-economic position
TLI	Tucker Lewis Index
UNICEF	United Nations International Children's Emergency Fund
WLSMV	Weighted least squares mean and variance adjusted
WRMR	Weighted root mean square residual

Ethical Approval

Ethical approval for this study was obtained from the London School of Hygiene & Tropical Medicine ethics committee.

Organisation of Thesis

The 11 chapters in this thesis are organised into six parts; the first part provides the introduction to the thesis and the final part is an overview. Each of the central four parts addresses one of the four main research questions of this thesis.

Part I: Background

In Chapter 1, I review the concept of socio-economic position (SEP), its measurement and its importance for epidemiology. I introduce the wealth index as a measure of SEP, identify some of the main concerns about the wealth index and present a literature review that describes the ways it is constructed and used in the published literature.

Chapter 2 comprises an overview of the data and methods I use in this thesis; I detail the sampling and key variables and describe the data cleaning and analysis methods.

Part II: What is the relationship between the wealth index and consumption expenditure?

The wealth index is often proposed to be a simple, reliable, and rational alternative to consumption expenditure, which is a preferred measure of economic position amongst many economists, but the data collection for which is too time-consuming for most epidemiological studies. I present a systematic review of the literature exploring the agreement of the wealth index with consumption expenditure in Chapter 3.

In Chapter 4, I construct a wealth index from the Malawi Integrated Household Survey 2004/5 (IHS2). I consider the relationship between consumption expenditure and the wealth index; quantifying the agreement using the IHS2. I explore whether this agreement is affected by how the consumption expenditure aggregate is calculated.

Part III: Are the methods used to construct wealth indices from DHS the most appropriate?

In Chapter 5, I explore the use of Principal Components Analysis (PCA), which is the most common method for weighting the indicators in a wealth index. I review the concerns about the use of PCA for wealth index construction, explore these concerns, and evaluate alternative methods for weighting the indicators.

Chapter 6 explores differences in characteristics of the wealth index across urban, peri-urban, and rural areas. Levels of agreement with consumption expenditure, systematic differences in whether a wealth index ranks households as higher or lower than consumption expenditure, and differences in the distributions were compared across the areas. The impact of removing urban-biased indicators from the wealth index is considered. I also explored the effects of constructing separate indices for each area.

In Chapter 7, I investigate the effect of increasing the number and variety of indicators used to construct the wealth index. Effects on wealth index distribution, urban-rural patterns, and agreement with consumption expenditure are considered.

Part IV: What socio-economic processes contribute to the wealth index hierarchy?

In Chapter 8, I explore the socio-economic processes that determine a household's position within the wealth index hierarchy. This analysis is conducted both for a wealth index constructed with and without indicators that primarily measure community-level services, and for the whole population as well as separately for urban, peri-urban, and rural areas.

Part V: What are the alternatives to the wealth index?

Chapter 9 identifies the potential alternatives to the wealth index. Advantages and disadvantages of the alternatives are discussed. I measure the agreement between the wealth index and the potential alternative SEP indicators, and explore the socio-economic processes underlying some of these alternative measures.

Chapter 10 compares the wealth index with potential alternative SEP indicators for different purposes: quantifying inequalities in health, exploring the determinants of health, and program targeting.

Part VI: Overview

In the concluding chapter I review the rationale, objectives and main findings of this thesis, and address methodological considerations. Finally I summarise the issues surrounding the wealth index, and draw overall conclusions and recommendations.

Publications arising from this thesis

Peer-reviewed publications

Howe, L.D., J.R. Hargreaves, and S.R.A. Huttly, *Issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries.* Emerging Themes in Epidemiology, 2008. **5**: 3

Howe, L.D., J.R. Hargreaves, S. Gabrysch, and S.R.A. Huttly, *Is the wealth index a proxy for consumption expenditure? A systematic review.* (In submission)

Conference presentations

Howe, L.D., J.R. Hargreaves, B. De Stavola, and S.R.A. Huttly, *Issues in constructing an asset index by Principal Components Analysis.* **Oral presentation,** XVIII International Epidemiological Association World Congress of Epidemiology, September 20-24 2008, Porto Alegre, Brazil

Howe, L.D., J.R. Hargreaves, S. Gabrysch, and S.R.A. Huttly, *Is the asset index a proxy for consumption expenditure? A systematic review.* **Poster presentation,** XVIII International Epidemiological Association World Congress of Epidemiology, September 20-24 2008, Porto Alegre, Brazil

Part I: Background

1. Socio-economic position and its measurement

1.1 Introduction

In this chapter, I provide a brief overview of the importance of socio-economic position (SEP) to health, the sociological and economic theories underlying SEP, and the various SEP measures used in epidemiological research. I then introduce the wealth index as a measure of SEP. I present a literature review of studies using the wealth index, detailing how, where, when, and why it is used. I briefly discuss what concept of SEP a wealth index may be measuring, and go on to describe the next steps in this thesis.

1.2 Socio-economic position and health

Nancy Krieger has argued that "by definition, the people we [epidemiologists] study are simultaneously social beings and biological organisms" and therefore that no epidemiological research should be carried out without considering the role of social factors.[1] It has been recognised for centuries that health is socially patterned (reviewed in [2], page 13). Disadvantaged social groups tend to suffer a disproportionate burden of ill-health, with higher mortality rates and greater incidence, severity and duration of many health problems (the evidence has been reviewed in several places, e.g.[3-9]). The social patterning of health is a consistent finding, with the picture being similar within and across populations, in many settings, across different times, in multiple studies, for varied outcomes, and using multiple measures of social conditions. The broad term socio-economic position is often used to encapsulate various concepts of social conditions relating to position within a social hierarchy. The reasons for the strong relationship between SEP and health are numerous, complex, and intertwined. Position within a social hierarchy is linked to the probability of health-damaging exposures, health damaging or enhancing behaviours, receipt and understanding of health promotion messages, health-enhancing resources, stress, sense of control, and other material and psychosocial factors that may affect health.[10]

In recent years, the interest of epidemiologists in social determinants of health has intensified[11] and there have been calls for a greater still focus on the social determinants of health in public health research.[12] As Krieger implied, almost all epidemiological studies require a measure of SEP. Studies focusing on the social determinants of health require measures of SEP to quantify and understand health inequalities, assess the effects of policies and interventions on different social groups, and develop and evaluate programmes designed to reduce inequalities. Measures of SEP are necessary for most observational studies, not just those focusing on social determinants of health. Since SEP is a determinant of most health outcomes and is also related to many of the exposures in epidemiological studies, it is likely to be a confounder of many of the relationships of interest to epidemiologists. There is also growing advocacy for recognition that equity is an essential element to programmes and targets such as the Millennium Development Goals,[13-15] necessitating measures of SEP for national and international statistics and monitoring.

1.3 Terminology

Socio-economic position is a broad-brush term frequently found in the epidemiological literature. Despite the widespread use of the term, SEP does not have a consistent or useful definition:

> *"A person's overall standing within a social stratification system... Imprecisions and uncertainties as to what such general notions refer to, compared with more analytically focused notions of class and status, have meant that the concept has attracted criticism."*(page 628[16])

Concepts, definitions, and measurement of SEP vary significantly across disciplines, researchers, settings, and studies. Grusky and Weeden describe the choice of measure as a "badge of affiliation".(page 20[17]) In general, SEP reflects the 'social and economic factors that influence what position(s) individuals and groups hold within the structure of a society'.(page 14[2]) Socio-economic position is an aggregate concept that encompasses both resource-based and prestige-based aspects of position within a social hierarchy.[18] For instance, income, education, wealth, and occupation are all considered to be measures of SEP. There is a generally accepted view that there is both independence and inter-dependence between the different aspects of SEP; i.e. they influence each other, modify each other's effects, but also operate through different pathways.[19] The term socio-economic *position* is considered favourable to socio-economic *status* because socio-economic status places too much emphasis on the status/prestige aspects of SEP.[20]

Many other terms for measures of position within a social hierarchy exist – social class, social stratification, and so on. The terms reflect different theoretical foundations, conceptual notions, and disciplines.

I use the term SEP in its broadest sense, without necessarily referring to a specific ideology or concept of social processes. Rather, I use it as an all-encompassing term covering the wide range of concepts and measures of position within a social hierarchy found in the social and health sciences.

1.4 What is socio-economic position?

Whilst social epidemiologists are interested in how social processes affect health, the theory underlying the generation of social structures comes primarily from the disciplines of sociology and economics. Despite the common origins and interests of epidemiology and the social sciences, few formal links exist between the two.[21] Unfortunately, it is common in the epidemiological literature to find the terms social class, social status, and socio-economic position used interchangeably[4], despite these terms having different theoretical, historical and disciplinary roots.[19] Equally, it is rare to see a justification of the choice of SEP indicator used in epidemiological research.

In this section, I outline the sociological and economic notions underlying SEP. This discussion will focus on household or individual SEP; community SEP, despite being a significant aspect of social stratification and an important determinant of health, is outside of the scope of this work.

1.4.1 Social stratification

Social stratification is defined as follows:

> *"The hierarchically organized structures of social inequality (ranks, status groups, etc.) which exist in any society. As in geology, the term refers to a layered structuring or strata, but in sociology the layers consist of social groups, and the emphasis is on the ways in which inequalities between groups are structured and persist over time."* (pages 621-623[16])

As is implicit in this definition, all human societies have social hierarchies. These hierarchies are shaped by numerous forces – historical, cultural, political, and economic. SEP is just one form of social stratification; others include gender, sexuality, and race/ethnicity. All of these forms of stratification create groups with an unequal share of advantage/disadvantage. This advantage or disadvantage can take several forms; power, control, access to resources, social standing, and so on.

1.4.2 Social status

The term 'social status' is defined by the Collins Dictionary of Sociology as:

> *"The positive or negative honour, prestige, power, etc. attached to a position, or an individual person, within a system of social stratification."* (page 654-655*[16]*)

1.4.3 Social class

Social class could be viewed as a hierarchical system of groups of individuals with a similar level of social status. In British sociology, class is generally viewed as an inherited trait, whereas status may be modified, for example through education or occupation.

Theories of social class have originated primarily from the works of Karl Marx and Max Weber. A third view of class is presented by the US Functionalist sociological tradition.

The Marxian view of class is that groups are defined on the basis of their relationship to the means of production. He believed that different systems of production result in different relationships between groups of individuals. Capitalism is a system of production that encourages production of commodities surplus to the needs of an individual and their dependents; this surplus is then traded in a market system. The Marxist view of class is therefore a dichotomised one; there are those who possess and control the means of production and those who do not. Marx believed that exploitation is an inevitable consequence of capitalism, because the benefits from surplus production are concentrated in few individuals and not those individuals whose labour produces the surplus. Under this theory, exploitation is not inherent in human society; rather it arises from means of production such as capitalism. Marx viewed class structure as being both a product and a determinant of societal patterns; classes arise from the nature of the means of production, but they also determine the destiny of a society and shape social forces and interactions, primarily because the exploiters need the exploited in order to maintain their position. Class as a Marxian concept is structural, i.e. it is determined by societal not individual forces.

Marxian thought has been incorporated into the class theories of other sociologists such as Erik Wright, who initiated and coordinated a multi-national programme of data collection for quantitative class analysis.[22] He has written extensively on class theory, including developing the concept of a middle class into a Marxian view of class. Wright states that the modern 'middle class' is characterised by both being exploiters and exploited.[2] He has argued that exploitation in modern capitalist society is on multiple levels, not just via the means of production: e.g. exploitation based on ownership of capital assets, control of organisational assets, and possession of skills.(page 15[2])

In contrast to Marx's view of stratification being based purely on relationships to the means of production, Weber saw society as being stratified in many different ways. He saw social position as having three constituents: class, status, and power. Class in the Weberian sense relates to economic resources such as income, status relates to prestige within ones community, and power relates to the political system.[19] These three elements come together to create groups that share similar levels of 'life chances'.[2] Life chances relate to the probability of 'procuring goods', 'gaining positions in life' and 'finding inner satisfaction'.(pages 77-82[16]) They are determined by education, skills and other attributes, and an individual's ability to benefit from these attributes. Weber therefore placed more emphasis on individuals and their ability to create life chances, and didn't share the Marxian view of stratification as structural. He believed that economic exploitation and other social forces alter the probability of opportunities, rather than inherently determining them. Most epidemiological measures of SEP have a Weberian focus, since they relate to individual rather than structural concepts.

A third school of thought in sociology that differs markedly from Weberian and Marxian theories is Functionalism. Functionalism arose from US sociology; it proposes social hierarchies as a natural and necessary feature of complex modern societies. Inequality is therefore inevitable and necessary for societal functioning under the Functionalist view; the approach is therefore used to legitimise the existence of inequalities. Structural features of the economic system are seen to be the driving force behind social stratification, rather than characteristics of the individual (pages 16-17).[2] Functionalist views and measures are rarely used in an epidemiological context.

1.4.4 Social stratification in different contexts

Most of the concepts discussed so far have arisen from academic study in industrialised settings. The relevance to less-developed settings could be questioned, particularly in settings where a majority of the population are subsistence farmers and so have limited interaction with the wider economy. Although all societies have hierarchical systems, the nature of these structures and beliefs surrounding them are context-specific. An important example of this is the Indian caste system, which historically stratified the population according to skills and type of work conducted. There is very little movement between castes, and caste is passed on between generations of a family. In today's society, therefore, an individual's caste is determined by the occupation of their ancestors. The significance of different determinants of social stratification varies between places; for example race is a far more important determinant of social stratification in Latin America than in many other regions of the world, and education grows in importance as it moves from being the privilege of the minority to being more widely accessible. Social stratification systems are also likely to change more rapidly in less-developed settings than in industrialised nations, where systems are relatively stable. This is because of rapid changes in urbanisation, access to education, industrialisation and the resultant changes in job opportunities, and so on.

1.5 Measuring socio-economic position

In all aspects of epidemiology, measurement matters. Without carefully considered and clearly defined exposure, outcome, and covariate measurement, epidemiological studies are worthless. Socio-economic position should be no exception to this rule. Measures of SEP should be selected in a study- and setting-specific way, rather than simply following convention or choosing measures on the basis of convenience. It is not necessarily the case that one SEP indicator is universally 'better' than others; different aspects of social and economic conditions may be more or less important for different diseases, or in different settings. Careful thought should go into determining the hypothesised pathways between SEP and health for a particular study, and the most appropriate SEP indicator(s). Health inequalities research should not operate in an academic vacuum; the results should be useful to policy-makers, and this should be an added important consideration in the selection of SEP measures. An SEP indicator should be, as with other exposures in epidemiology, an exposure amenable to social policy interventions. This requires a clear understanding of the socio-economic processes being captured by the SEP indicator, and knowledge of its causal relationship to health.[23]

In this section I review some of the most common indicators of SEP and their measurement.

1.5.1 Education

Education is considered to measure both resource and prestige aspects of SEP.[18] Education therefore straddles Weber's class and status domains.[19] Since education rarely changes after early adulthood, it is often used to reflect early life experiences when looking at inequalities with a lifecourse perspective.[24] Education is a very frequently used measure of SEP; it is easy to measure, not generally a sensitive subject to ask questions about, and not subject to large recall bias.

Other aspects of SEP are related to education; it strongly determines both income and occupation, and is also in itself affected by parental SEP. Different groups within a society may get different economic returns for the same level of education – e.g. women and ethnic minorities may benefit less from the same educational level as men and those in majority groups.[19] There are also likely to be cohort effects, since the availability, accessibility, and importance of education will change over time.

Education is measured in a variety of ways; most commonly highest grade achieved, number of years completed, or highest qualification. The proposed mechanism linking education to health should guide the choice of measure; is it that every year spent in education leads to an increase in health, or that reaching certain milestones is what matters? This will differ between countries and populations, and will change over time, especially with women and rural populations in low-income settings, whose educational possibilities are rapidly changing. Measures of education generally have no indication of the quality of education received (page 57)[25]. Literacy is sometimes used in preference over education measures because it can be viewed as capturing the skills gained through education that are important for income and occupation potential.

Education involves learning facts, concepts, and how to access information.(page 22[2]) It may, therefore, make individuals more receptive to health messages, more able to access health services, and more likely to invest in behaviours with long-term health benefits.(page 56[25]) There is also a reciprocal relationship between child health and educational achievement, since chronic ill-health in childhood may limit educational achievement. Blane proposes at least five pathways between education and adult health[26]:

1. A child's education is affected by its family's resources, so effects of education on adult health could be reflective of the influence of childhood circumstances
2. Education strongly effects income and occupation in later life
3. Education may affect how receptive an individual is to health messages, both because of ease of understanding these messages and because education may lead to material and cultural resources that facilitate behaviour change
4. A background factor may influence both the ability of an individual to successfully complete education and their ability to maintain health
5. Ill health in childhood can affect educational achievement and is also strongly predictive of adult health

1.5.2 Occupation

Many occupations have direct effects on health, for instance job involving hazardous substances or hard labour. More generally, occupation is believed to affect health both through income (and hence access to material resources) and through psychosocial pathways operating through occupational prestige, sense of control, stress, and social networks. The Collins Dictionary of Sociology defines occupational prestige as follows:

> *"The subjective evaluation of the 'social honour' or 'standing' attached to an occupation..."*(page 457[16])

Occupational prestige can be viewed as having elements of Marxian, Weberian, and Functionalist theory. In Weberian terms, occupation straddles Weber's class and status domains[19]; in Marxian terms occupation would be divided on the basis of being exploited or an exploiter. Occupation is strongly related to both income and education.

Occupational prestige measures have been extremely popular in high-income countries, especially in the United Kingdom, where occupation is recorded on death certificates. It has been far less widely used in low-income settings. Various schemes exist for classifying occupations in Britain and other industrialised settings. These classification schemes may incorporate concepts of autonomy and job control, promotion prospects, job stability, ability to hire others, educational requirements of the job, and so on. Such classification schemes and measurement scales are not readily transferable to low-income settings.

One limitation to occupational measures is that unemployed people are often missed out, as are retired people, people whose work is mainly in the home (primarily affecting women), students, and those working in unpaid/illegal/informal jobs.(page 49[25]) For women, husband's occupation is often used, but this requires a set of assumptions about the status of women, the roles of husbands and wives, and the mechanisms linking occupation to health. Similarly, the occupation of the head of the household is often used to categorise the rest of the household, also necessitating assumptions about the pathways between occupation and health. In low- and middle-income countries, categorisation of occupations is more complex than in more industrialised settings. People may have multiple jobs, or be reliant on casual/temporary jobs, or employment may be seasonal.

1.5.3 Income

Income is an attempt to measure material living standards, and is therefore primarily used in epidemiology when a material explanation for health inequalities is hypothesised. Income is also tied in with concepts of prestige, although its primary mode of action is believed to be through command over material resources. Income is generally hypothesised to affect health through the increased consumption of health enhancing commodities, such as food, shelter, and access to health services.(page 58[25]) There is also likely to be a bidirectional relationship between income and health, whereby ill-health leads to a reduction in income. Income may fluctuate over time more than most other SEP indicators, although this is largely ignored in epidemiological studies.[27]

Income is generally collected at the household level, and adjusted for household size and composition using an equivalence scale. Multiple sources of income should be included when collecting income data, e.g. formal employment, informal employment, remittances, benefits, income from rental properties, etc.

Since income is a particularly sensitive topic and interviewees may be reluctant to divulge the information, proxies for income are often used. Examples include tax band, or council tax band in the UK. Alternatively, questionnaires may include pre-defined income categories, which may be a less sensitive way of asking about income and hence yield a better response rate.

1.5.4 Consumption expenditure

Friedman's 'permanent income hypothesis' suggests that there are two dimensions of income – planned and anticipated, and current income.[28] Planned and anticipated income is referred to as 'permanent income'. Friedman argued that individuals and households base their consumption decisions primarily on their permanent income rather than on their current income. An example of this would be that a medical student may exercise higher consumption than a nursing student, since the former anticipates a higher long-term income. Under this theory, consumption is 'smoothed' in response to fluctuations in income, for example by utilising savings, borrowing, or, for more long-lasting shocks, selling assets. In addition, large irregular incomes such as bonuses might be at least partially saved. Current income is in any case hypothesised to affect health primarily through its effect on consumption. Since consumption may be a more accurate representation of long-term economic position, it could be argued that it is a more useful SEP indicator than income. This is particularly true in health research, where it is long-term SEP rather than recent conditions that is more likely to affect many, although not all, health outcomes.

Consumption expenditure, where expenditures on a wide range of items are summed to form an aggregate measure of total expenditure, is an attempt to measure actual consumption. Despite consumption smoothing, consumption expenditure has been shown to vary considerably over time (summarised in [29]).

Consumption expenditure data are difficult and costly to collect. In some circumstances, expenditure diaries can be used to collect consumption expenditure data prospectively. In this case, each member of a household may be asked to complete a diary of all expenditures each day for a certain period. The period of data collection must be sufficient to overcome the 'prestige effect', whereby expenditures fluctuate according to time in relation to receipt of income, etc.[30] This method of data collection, however, is expensive, complex, and time-consuming. It necessitates repeat visits to households to ensure that they are completing the diaries correctly, and often has considerable drop-out rates, leading to bias.[30] It also requires the respondents to be literate. For these reasons, the diary method is unfeasible for most research in low-income settings. Consumption expenditure data collection methods have therefore been developed for large household surveys in low- and middle-income settings. In this situation, a long list of potential expenditure items are included on the questionnaire and respondents are asked to report frequencies and quantities of purchases, as well as expenditure amounts. Since home-produced goods and goods received in kind are particularly important in many low- and middle-income settings, these are also included in the questionnaire. Their values in terms of cash expenditures must then be estimated.

Data collection for expenditures using a single retrospective questionnaire means that data are often collected from a single household member, despite consumption not being equally distributed across household members. The choice of equivalence scale used to adjust the aggregate expenditure can have a large effect on the final measure.

There are questions over the reliability of consumption expenditure measures generated through survey methods, since recall of expenditures may be problematic, and a number of significant assumptions are required to calculate the aggregate measures. Estimating expenditures on foods eaten outside of the household is considered particularly problematic, since accurate data collection would require interviewing every household member; such expenditures are, however, often a relatively small proportion of total food expenditures in low- and middle-income settings.[30] A value must be imputed for all home-produced goods and those received in kind. This is often done using a price index; market price data are collected for each item across different regions, adjusted to remove the estimated costs of transport and distribution that do not apply to home-produce so as to give farm-gate rather than market-gate prices, and subsequently applied to estimate the expenditure value of the home-produced goods for each household.[31] Estimations of the value of home-produced goods may introduce bias for a variety of reasons. For instance, the produce retained by households for own consumption could be of differing quality to that sold on at markets.[31] The imputed values of home-produce have been shown to be less variable than the true data would be, leading to the underestimation of poverty and inequality.[31]

Seasonality is an issue for both purchased and home-produced goods, but is perhaps most likely to affect rural households.[30] Recall periods will affect the impact of seasonality on the final consumption aggregate, e.g. recall periods used in the questionnaire should differ for items consumed soon after harvest and those stored for gradual use.[30] Living Standards Measurement Surveys often ask about a 'typical month', as well as asking how many months per year the food is typically consumed.[31]

Despite these concerns, there is widespread consensus amongst economists about the value of consumption expenditure as a measure of living standards, particularly in low-income country research.[31]

Further issues with consumption expenditure data include the issue of what time period to ask questions about, since some purchases are irregular and/or infrequent, but recall can be an issue; and also it is unclear what sorts of expenditures should be included, i.e. large irregular expenditures such as funerals and weddings, health expenditures, and so on. It is difficult to capture the effect of preferences when measuring consumption expenditure, for instance someone who chooses to be a vegetarian is not the same as someone who cannot afford to buy meat, but it would be difficult to capture this. Collection of consumption expenditure data generally requires a lengthy, time-consuming questionnaire requiring specialised interview training. There is, however, some evidence that consumption expenditure can be accurately estimated using a fairly short list of items, thus reducing the costs of data collection.[32]

1.5.5 Wealth

Wealth is a measure of long-term economic position; it reflects accumulated assets that can be drawn upon in times of economic instability such as short term unemployment or illness. The full definition of wealth is:

> *"The total value of a person's net assets. Wealth may be held in various forms: these include money, shares in companies, debt instruments, land, buildings, intellectual property such as patents and copyrights, and valuables such as works of art. From this, any debts are subtracted. The valuation put on these things is liable to uncertainty and fluctuations, as many of the assets are not marketed, and those that are may have volatile market prices. The wealth of individuals is believed to affect their choices about both consumption and money holdings..."*(page 501[33])

Wealth can be considered to be a measure of Weber's class domain. Wealth is related to, but not the same as, income. Accumulated income is one aspect of wealth. There may be, however, marked differences in wealth between households with the same income, for instance race differences in wealth in the US are far wider than race differences in income.(page 27[2]) Wealth is often considered more difficult to measure than income or consumption expenditure, and so is less frequently used.(page 44[34])

For a full measure of wealth, a wide variety of assets would need to be included. The types of assets that are reflective of wealth would vary between places and over time, since asset ownership is affected not only by affordability but by preference, availability, and culture. Housing quality is one type of asset that forms part of total wealth. As an example of how a measure of wealth would need to differ across place and time, the most appropriate materials for constructing a dwelling differ according to climate, local availability of materials, and so on.

1.6 Money-metric or multi-dimensional measures?

Income, consumption expenditure, and wealth are primarily measures of economic position; they mostly reflect material living standards. There is now widespread acknowledgement that the social processes that are important for health are not solely economic. Social constructs such as gender[35-40], race/ethnicity[41-45], and social capital[46-54] have all been shown to be important determinants of health. Being a part of any minority or discriminated-against group may lead to an increased risk of ill-health.[55] Despite this recognition of the multifaceted nature of social determinants of health, money-metric measures remain widely used. This may, in part, reflect the difficulty of operationalising multi-dimensional concepts of social hierarchies. It may also be an attempt to make research more policy-relevant, or at least to speak the language of policy makers. There may also be a wish to separate out economic and other effects, and therefore use an economic indicator separately from other social indicators.

1.6.1 Money-metric measures in low- and middle-income settings

Income and consumption expenditure are both widely used as indicators of economic position. Both these measures, however, are costly and difficult to collect reliably in low-income settings.

Income is particularly difficult to measure in low-income countries where households may have multiple sources of income, including home production; income may vary substantially between seasons or years; income may sometimes be in the form of goods, which are difficult to place a monetary value on; multiple household members may have an income but household income data is frequently estimated by questioning a single household member who may have incomplete knowledge of all income sources, and generating income can have costs to the household in terms of lost home-production.

Additional to the difficulties in collecting accurate data on all sources of income, individuals may lie about their income or be reluctant to disclose it to interviewers. Thus income data in developing countries is highly likely to suffer from poor reliability, with differential misclassification. Inaccurate reporting of income is particularly likely if respondents think that the data is going to be used for other purposes; for instance income may be under-reported if respondents suspect the information will end up with the tax office or if they believe reporting a low income will result in the provision of financial or other support.

Consumption expenditure, despite generally being preferred to income, is also fraught with measurement difficulties.[31] Measuring consumption expenditure requires a lengthy questionnaire covering a wide range of items. The respondent may not know or not remember all expenditures for all items. A multitude of assumptions and estimations are required for consumption expenditure measurement. The value of home-produced goods needs to be estimated; adjustments are required for price differences across areas and times (if data collection was carried out over a large geographical area with different prices or over a prolonged period of time over which prices will have changed), and the rental value of owner-occupied housing must be estimated. This latter estimation is often particularly problematic in low-income countries, where rental markets may be limited or non-existent.[32] Measurement of consumption expenditure is also particularly time-consuming, taking up to an hour of interview-time.

1.7 The wealth index as a measure of socio-economic position

A wealth index is a composite measure of, typically, indicators of ownership of consumer durables, housing characteristics, and access to public services. It is used as a measure of SEP in low- and middle-income countries. A wealth index is referred to variously as an asset index, a living-standards index, or simply a socio-economic index. I will use the term wealth index in order to be consistent with the terminology used by those primarily responsible for developing and popularising the method.[29, 56]

The wealth index approach has arisen from demographic studies such as the Demographic and Health Surveys (DHS). There was growing interest in using the high quality, nationally-representative, and internationally comparable health data in the DHS to quantify and compare socio-economic inequalities, but the DHS do not contain any economic indicators such as income or consumption expenditure. The DHS do, however, collect information on ownership of a range of durable assets (e.g. car, refrigerator, television), housing characteristics (e.g. material of dwelling floor and roof, main cooking fuel), and access to basic services (e.g. electricity supply, source of drinking water, sanitation facilities). These items were all originally included in the surveys for their direct influences on health, for instance television and radio ownership was of interest to identify households receiving public health messages. Researchers began to see that these assets could be used as indicators of living standards and started constructing wealth indices for that purpose.[56, 57] Staff at the World Bank, DHS and Macro International began to explore the use of wealth indices within DHS datasets, and published several methodological studies advocating the approach, including the seminal paper by Filmer and Pritchett.[29] They have since presented a series of analyses of DHS datasets from 56 countries using the wealth index to quantify socio-economic inequalities in a range of health and nutrition outcomes, lead by Davidson Gwatkin.[58] As well as its use for measuring SEP in existing datasets where no alternative economic measures are available, the wealth index approach is now widely used in primary data collection in low- and middle-income countries. Both academics and NGOs have adopted the approach; for instance UNICEF altered the questionnaires for their Multiple Indicator Cluster Surveys (MICS) in order to be able to construct a wealth index comparable to that used in the DHS.[59]

The wealth index has been claimed by some proponents to provide a rational, simple and reliable alternative to consumption expenditure.[29, 58] This is attractive to researchers wishing to use the wealth index for primary data collection, since the collection of consumption expenditure data is generally considered unfeasible for most epidemiological studies due to the length of time required to complete a consumption expenditure questionnaire module. It is also attractive to those concerned about the reliability of consumption data, since the wealth index approach relies on simple questions less likely to suffer from recall bias than expenditure questions.

The wealth index is a measure of relative rather than absolute SEP; it can only be used to assess SEP ranking within a hierarchy across a population. This is in contrast to measures such as income or consumption expenditure, which have an 'absolute' value and can therefore be compared across as well as within populations. This means that wealth indices cannot be used to construct poverty lines and quantify the levels of poverty within a population in the same way as income or consumption expenditure can be.

Wealth indices measure SEP at the household level. Using a household-level SEP measure has limitations, since individual-level SEP indicators arguably are more amenable to effective policy interventions[60] and household and individual SEP may affect health through different pathways.[61] This limitation is not, however, limited to the wealth index; income and expenditure are also often used as household-level indicators

1.7.1 Constructing a wealth index

When constructing a wealth index from a set of variables, a decision must be made about the weights to assign to each indicator. The easiest method would be to use a simple sum of the number of indicators each household has. This has the disadvantage of being arbitrary; each indicator has the same weight (one) and so is implicitly given equal value in terms of SEP. Alternative methods attempt to use price information to value the items, or assign weights according to the inverse of the proportion of the population owning the item (such that rare items are given a higher weight than widespread ones). A further option is to use a statistical procedure. Principal Components Analysis (PCA) was recommended as a method for determining weights for components of a wealth index by Filmer and Pritchett.[29] Guidelines for the use of PCA for wealth indices were published by Vyas and Kumaranayake.[62]

Various concerns about the use of PCA to construct wealth indices have been expressed. These include: i) the method is complex and could be accused of obscuring the process of index construction, and ii) PCA is intended for continuous variables, but is frequently applied to binary and categorical indicators for wealth index construction.

A further concern about the construction of wealth indices is the choice of indicators. Those used in the DHS were selected because of availability, rather than based on any theoretically-based hypothesis. The extent to which these indicators have been adopted by those using the wealth index approach in primary data collection, and the approaches used to select indicators for wealth indices are unknown.

Finally, the DHS tend to generate one wealth index for a whole country, such that PCA is performed for urban and rural areas combined. It is not known whether this is the most appropriate way of constructing a wealth index, or whether this is how those using the wealth index in primary data collection also tend to create the wealth index. One potential problem with creating a single index for urban and rural areas is that many of the indicators in the DHS wealth index could be described as having an 'urban bias'; i.e. urban households are far more likely to have access to improved water and sanitation, have an electricity supply, and live in a dwelling constructed from modern rather than traditional materials compared with rural households. Vyas & Kumaranayake discuss how the distributions of wealth indices tend to differ across countries and areas within a country; there is frequently either clumping (where a large proportion of households have the same wealth index score, typically a low score in poor rural areas), or truncation (where the tail of the distribution is cut short).[62]

1.7.2 Does a wealth index measure wealth?

The term wealth index is used by those employing the approach with DHS data. The authors of the overview report into inequalities in DHS from 56 countries acknowledge that the wealth index should not be seen as a measure of wealth in terms of the strict economic definition of wealth.[58] The indicators used to construct wealth indices for the DHS were selected primarily because of availability and convenience, and are unlikely to be the best indicators of wealth.

A key point arising from the definition of wealth is that wealth means the **value** of assets; wealth indices do not generally incorporate information on asset value, or even on the age or quality of assets. Although some attempts have been made to incorporate prices and value into wealth indices, this is not common practice and attempts have shown difficulties in reliability.[63] A further key point arising from the definition of wealth is that debts should be subtracted from the value of assets. To my knowledge, no attempt has been made to incorporate debts into a wealth index.

1.7.3 What does a wealth index measure?

Although it may not be a measure of 'wealth' itself, the wealth index is frequently proposed as a measure of long-term economic position. Specifically, some proponents of the wealth index view it as a simple, reliable, and rational proxy for consumption expenditure.[29, 56, 58] A wealth index could be theorised to represent long-term SEP in a similar way to consumption expenditure; asset ownership is likely to be based at least partially on economic wealth and household assets are unlikely to change in response to short-term economic shocks. There is, however, uncertainty about the appropriateness of considering a wealth index as a proxy for consumption expenditure. Two separate studies have demonstrated weak correlation between consumption expenditure and wealth indices: a study in Mozambique showed a Spearman's rank correlation coefficient of 0.37[64], and a study using multiple datasets produced R^2 values from regressions of consumption expenditure on a wealth index of ≤ 0.23.[65] A study using Indonesian data found that there was considerable re-ranking of households between a wealth index and consumption expenditure, with approximately 50% of households being differentially classified when the population was split into the bottom 30%, middle 40% and top 30%.[66] Other studies have demonstrated considerable variation in the correlation across countries, with Spearman's rank correlation coefficients between 0.43-0.64 in one study and 0.39-0.71 in another.[29, 67] There is very little research exploring the relationship between the wealth index and SEP indicators other than consumption expenditure, meaning that there is considerable uncertainty about the socio-economic processes being captured by a wealth index.

1.8 The use of wealth indices as a measure of SEP

In this section, I review the use of the wealth index as a measure of SEP in the published literature. Despite the apparent widespread use of wealth indices, there is no clear picture of how and where they are used, and whether they are constructed and used in similar ways by different researchers. Furthermore, it is not clear what concepts of SEP researchers hypothesise that the wealth index is capturing, and whether researchers generally rely on the wealth index as their sole measure of SEP, or whether it is used in conjunction with other SEP indicators.

1.8.1 Objectives

The aim of this review is to describe the ways that wealth indices are currently used in the published literature, and the available evidence relating to their relationships with other SEP indicators. Specific objectives are:

1. describe where and how wealth indices are used as a measure of SEP, in terms of which settings they are used in, in which types of study, and with which outcomes of interest
2. describe variations in the ways wealth indices are constructed
3. describe whether wealth indices are used alone or in conjunction with other SEP indicators

1.8.2 Methods

A very large number of studies have used the wealth index approach to SEP measurement. The aim of this review is not to obtain all, or even a representative sample of studies using a wealth index; rather it aims to get a broad overview of the range of practice in wealth index use. The chosen approach to identify studies is to review those citing Filmer and Pritchett's key wealth index paper.[29] This paper is one of the best known pieces of methodological research on the wealth index approach; it arose out of discussions between researchers at the World Bank and DHS wishing to develop the methodology, and is cited by the reports using the wealth index approach in DHS studies as justification for the method.[56, 58] Although not all studies using a wealth index will have cited the Filmer and Pritchett paper, it is hoped that since this is a relatively novel method, a substantial number of studies will have done.

A Web of Knowledge search was carried out to identify papers citing Filmer and Pritchett's paper (performed on the 16th January 2008). All papers citing Filmer and Pritchett were reviewed to explore where and how wealth indices are used.

1.8.3 Results

A Web of Knowledge search to identify papers citing Filmer and Pritchett's paper identified 193 papers (including five that had cited incorrect page numbers). One study was published in a non-English language journal amd was excluded from this review.[68]

1.8.3.1 Outcomes

The papers citing Filmer and Pritchett are interested in a wide range of outcomes, encompassing health research, demographic research, and economic research. Some examples of the outcomes covered are: infectious diseases[69-74], nutritional status[42, 75-79], health-seeking behaviour[80-86], child development[87-89], school enrolment[90, 91], demographic outcomes[92-94], health behaviours[84, 95-98], coverage of interventions and programmes[99-102], economic outcomes[103, 104], and a range of other health outcomes[39, 105-109].

1.8.3.2 Geographical regions

All of the identified papers focus on research conducted in low- and middle-income countries. Studies were from a range of contexts, both urban, rural, and mixed urban-rural. One study specified that wealth indices were constructed separately for urban and rural areas in order for the weights to reflect the differential importance of assets in each area[110]; in all other studies in mixed urban-rural areas, it is assumed that a single wealth index was constructed for the whole population.

Many countries were represented, from several continents including North Africa [111, 112], Sub-Saharan Africa[113-115], South Asia[81, 101, 116, 117], South East Asia[118-121], Eastern Europe[122], the middle East[102], and South America[80, 123, 124].

1.8.3.3 Constructing the wealth index

Filmer and Pritchett include a range of consumer durables, housing characteristics, and access to service indicators in the wealth indices they use.[29]

There was considerable variation in the number and type of indicators used to construct the wealth indices. Whilst some studies included only durable assets[71, 81, 83, 84, 94, 108, 125-131], the vast majority of researchers used a range of durable assets and housing characteristics similar to those used in the DHS (including dwelling materials, fuels for cooking or lighting, sanitation and water facilities). The overview report on socio-economic differences in health in DHS studies explicitly states that the indicators used to construct the wealth indices were chosen because of data availability rather than for theoretical reasons, and that these indicators may not be the optimal ones (page 3)[58]. Despite this, these indicators appear to have been accepted by a large segment of the research community as a 'standard' set of indicators for wealth index construction. There is, however, variation in the number and exact set of indicators used. Indicators other than those used in the DHS were included by a reasonable number of studies. The most common of these additional variables was education[65, 67, 72, 75, 76, 87, 97, 114, 115, 132-137]; this related mostly to the education of the household head, although occasionally parental education was included when the outcome of interest was child health. One study included parental literacy.[116] Occupation of the household head/parents or income source(s) was also included in a number of indices.[75, 76, 87, 96, 97, 114, 115, 132, 133, 136-138] Other household head characteristics such as age[65, 136, 139] and gender[112, 139] were also included by a few researchers. Land ownership was included by some researchers[69, 70, 73, 75, 76, 87, 116, 140, 141], and livestock was included by a reasonable number of studies.[70, 73, 97, 102, 109, 115, 116, 138, 141-145] A few researchers incorporated measures of food consumption expenditure in the wealth indices.[82, 146-152] One study included an indicator of urban/rural residence in the wealth index.[112] In many cases, the exact indicators included in the index are not reported in the paper (e.g. [42, 74, 78, 80, 86, 92, 93, 98, 99, 117, 119, 153-163]).

It was extremely rare for the papers to include justification for the choice of indicators included in the wealth index. One paper reported that local experts had been consulted for advice about selecting locally relevant items[134], another had used an existing dataset to identify variables correlating with consumption expenditure[164], two studies stated that they were aiming for cross-country comparability so had selected variables available in all of their datasets of interest[65, 109], two studies openly acknowledged that they were selecting variables on the basis of data availability[85, 165], one study reported that they had selected different items for different countries based on what was most likely to be relevant to that context – e.g. livestock for more rural-based economies[102], one study selected the items most strongly predictive of health[112], and one study identified those assets they believed least likely to be sold in times of economic hardship because they were looking for a stable measure of long-term wealth[121]. Several studies either did not include water and sanitation in the wealth index, or included them as separate variables/indices in analysis.[81, 139, 166]

Although the majority of papers used Principal Components Analysis (PCA) to construct the wealth index, very few reported the weights assigned to each indicator. No papers detailed or discussed their approach to dealing with categorical variables in PCA, and only a handful of papers acknowledged that PCA is intended for use with normally distributed continuous data. Other methods used by a minority of studies included equal weights (simple sum of indicators), weights equal to the inverse of the proportion of households owning an asset, and factor analysis.

1.8.3.4 Reason for using the wealth index

Of the papers in this review, the majority use a wealth index to explore determinants of an outcome, to quantify inequalities (this includes papers where only a univariable analysis of a wealth index – outcome relationship is presented), or to adjust for the confounding effects of SEP (**Table 1.1**). There were also a number of papers that did not include analyses using a wealth index – these included discussion pieces, reviews of SEP measurement, studies using PCA for other purposes, and studies referring to the wealth index approach for other reasons. A small number of methodological

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studies were also identified, which considered the wealth index approach but did not present analysis exploring the relationship of the index with an outcome. A few studies have wealth as an outcome.

Table 1.1: Ways in which wealth indices were used in papers citing Filmer and Pritchett

Use of wealth index	Number of papers	References
Exploring determinants of an outcome	69	[39, 65, 72-74, 82-86, 94, 100, 109, 111, 113, 123, 125-127, 146, 155-160, 162, 164, 165, 167-187][88, 89, 97, 119, 128-131, 143-145, 147, 161, 166, 188-191]
Measuring inequalities in an outcome	53	[67, 95, 96, 101-103, 110, 112, 114-118, 124, 135-140, 142, 148-152, 163, 192-215]
Controlling for confounding by SEP	33	[42, 69-71, 75-81, 87, 90-93, 98, 99, 105-108, 132-134, 153, 154, 216-219]
No WI used in the paper	25	[14, 220-243]
Methodological exploration of the wealth index	8	[62, 63, 66, 122, 244-247]
Wealth was an outcome in the study	4	[121, 141, 248, 249]

1.8.3.5 Use of the wealth index in conjunction with other SEP indicators

Of the 33 studies using a wealth index to control for confounding, 11 relied solely on the wealth index as the only measure of household or individual SEP (I have not considered measures of community SEP in this review). Of the remaining 22 studies, the most common additional SEP indicator was education[42, 71, 77-81, 92, 93, 98, 99, 104, 106-108, 133, 134, 217-219] – both maternal education and education of the household head were common, but some studies also used paternal education or the highest education level of any household member. A number of studies also controlled for occupation or employment.[78, 92, 98, 99, 104, 107, 154, 218] Occupational or employment measures varied from specific categories of occupation, to measures of occupational class, to broad categorisations such as agricultural or non-agricultural, to simple indicators of whether or not the household head/parent was employed at all. One study controlled for income[154] and another for consumption expenditure[218] – it was not clear why a wealth index was being used in addition to these more conventional economic measures. Several studies from India also controlled for caste[78, 81, 98], and two studies also included a measure of literacy.[81, 134] The choice of SEP indicator for confounding control was very rarely justified or discussed.

Of the 69 studies using a wealth index as part of an exploration of the determinants of an outcome, 15 used only the wealth index as a measure of SEP, and the rest contained multiple indicators of household or individual SEP. Again, the most common additional SEP variable was education[83-86, 88, 89, 97, 109, 111, 119, 125-131, 143, 147, 156-160, 165, 166, 171, 173-191, 250], and again measures of household head, maternal and paternal education were used. As with confounding control, the next most common additional SEP indicator was occupation/employment, and similar types of indicator were used.[111, 119, 127, 129, 143, 145, 171, 183, 185, 188, 190, 250] Other SEP indicators included in these analyses were caste[39, 126, 129, 188], gender of household head[184], subjective social status[111, 127], income[127], and literacy[129]. As with studies using the wealth index to control for confounding, it was extremely rare for papers to have any justification for the choice of SEP indicators used.

Where multiple SEP indicators were used, there was wide variability in whether they had independent effects on the outcome – this would appear to depend on the outcome, the setting, and the other variables included in analyses.

1.8.4 Conclusion

This literature review has confirmed that the wealth index is a very widely-used measure of SEP. It has demonstrated that the wealth index is used in a variety of ways by different researchers, but that the methods used to construct wealth indices within DHS data are the most common – the majority of studies included a similar number and range of indicators in the wealth index to the DHS, and used PCA to weight the variables. I have also demonstrated that a considerable percentage of studies using the wealth index to explore the determinants of an outcome or to control for socio-economic confounding relied on the wealth index as the sole indicator of SEP.

1.9 Thesis justification, research questions, and objectives

The findings from the literature review presented in **Section 1.8** will now be used to outline the justification for this thesis, and to identify the primary research questions to be addressed. For each research question, I outline the main objectives to be addressed.

1.9.1 Thesis justification

1. The wealth index is a widely used measure of SEP, both in secondary data analysis and in primary data collection, but there is currently a limited amount of methodological work focusing on the approach.
2. Some proponents view the wealth index as a simple, rational, and reliable proxy for consumption expenditure; the extent to which this claim is justified is not known.
3. Principal components analysis (PCA) is the most widely-used method for weighting the indicators in a wealth index (**Section 1.8.3**). There are important concerns about the use of PCA for this purpose. The practical implications of these concerns and potential alternatives to PCA have received little attention in the literature.
4. Wealth indices are often constructed for mixed urban-rural areas, despite the fact that many of the indicators commonly-used have an 'urban-bias'. The consequences of this are not known.
5. Although there is variety in the number and types of indicators used to construct a wealth index, many researchers collect and use a similar set of indicators to those used in DHS wealth indices. The consequences of using different numbers and types of indicators are not known.
6. The wealth index demonstrates strong and consistent relationships with health across a range of outcomes and settings. It is used for monitoring and comparing health inequalities, for controlling for the confounding effects of

SEP, and for evaluating the equity impact of policies, programmes, and interventions. Despite this wide-ranging use of the approach, the socio-economic processes being captured by the wealth index remain largely unexplored and unknown, leading to uncertain interpretation and policy relevance of results using the wealth index.

7. The range of SEP indicators used in epidemiological studies in low- and middle-income countries is fairly limited, with the wealth index, education, and occupation/employment being by far the most widely used measures. There is little discussion in the literature of alternative options for the choice of SEP indicator in epidemiological research in low- and middle-income settings, and the implications of using the wealth index instead of potential alternative indicators are not known.

1.9.2 Thesis aim

The overall aim of this thesis is to explore the wealth index as a measure of socio-economic position, and provide guidance to researchers about whether and how to use a wealth index as a measure of SEP. Issues in both the construction and use of wealth indices will be considered.

1.9.3 Research questions

Four overall research questions will be addressed in this thesis:

1. What is the relationship between the wealth index and consumption expenditure?
2. Are the methods used to construct wealth indices with DHS data the most appropriate?
3. What socio-economic processes contribute to the wealth index hierarchy?
4. What are the alternatives to the wealth index?

1.9.4 Thesis objectives

I here outline the main objectives for the thesis as a whole; more detailed objectives will be presented within each chapter. Hypotheses will be presented, where appropriate, within each chapter following a consideration of the issues involved in each topic of analysis.

Research question 1:

What is the relationship between the wealth index and consumption expenditure?

1. To conduct a systematic review of the literature evaluating the ability of a wealth index to act as a proxy for consumption expenditure.
2. To quantify the agreement between the wealth index and consumption expenditure, and explore the effect of the equivalence scale used to adjust expenditure for household size and composition on this agreement.
3. To explore whether the agreement between the wealth index and consumption expenditure is affected by the items used to construct the expenditure aggregate.

Research question 2:

Are the methods used to construct wealth indices with DHS data the most appropriate?

4. To explore and evaluate issues in the use of principal components analysis as a method for weighting the indicators in a wealth index.
5. To explore approaches to wealth index construction for separate areas (urban and rural) and compare these area-specific wealth indices with indices generated for the whole population.
6. To evaluate the effects of including and excluding different sets of indicators in the wealth index.

Research question 3:

What socio-economic processes contribute to the wealth index hierarchy?

7. To explore the determinants of wealth index scores, and hence to attempt to improve interpretation of the results of analyses using the wealth index.

Research question 4:
What are the alternatives to the wealth index?

8. To explore potential alternative SEP indicators.
9. To explore the consequences of using the wealth index instead of potential alternative SEP indicators.

1.10 Next steps

In **Chapter 2**, I describe the data and methods for this thesis. I present the two datasets I will be using, outline features of the data, key variables, and the overall analysis methods to be used.

2. Data and Methods

This chapter provides a summary of the two datasets used in this thesis – the Malawi Integrated Household Survey 2004/2004, and the Brazil Demographic and Health Survey 1996. The survey coordination, objectives, sampling methods, and key variables are described. Finally, some general information about statistical analyses is presented; specific methods will be detailed in each chapter as appropriate.

2.1 Choice of datasets

Two datasets were used in this thesis: The Malawi Integrated Household Survey 2004/2005 (IHS2) and the Brazil Demographic and Health Survey 1996 (DHS).

When choosing the dataset to be used for the main analyses of this thesis, the following features were considered important: all key indicators used by the DHS to construct a wealth index, a broader range of potential wealth index indicators to investigate the effects of their inclusion, data from both rural and urban areas, consumption expenditure data to use as a benchmark against which to compare the wealth index, a range of other socio-economic indicators to compare with the wealth index. All of these are features of a typical Living Standards Measurement Study (LSMS). The LSMS is a World Bank initiative, that aims to improve the quality of household data collected by statistical offices in low- and middle-income countries.[251] LSMS datasets typically contain a very wide range of SEP indicators, including both typical wealth index indicators, other assets and potential variables for wealth index construction, and comprehensive consumption expenditure data. The Malawi IHS2 is an LSMS. This dataset was chosen in preference to other LSMS because it has a large sample size, is relatively recent, and includes both rural and urban areas. The ease of data access was also a factor taken into consideration; many LSMS datasets require permission from the country statistical office before they can be downloaded and used. At the time of commencing this thesis, the World Bank LSMS website provided a rating of the ease of obtaining the data, considering other data users' experience of the reliability and speed of responses to requests from the national statistics offices (this information has since been removed from the website); Malawi was considered relatively simple and rapid to obtain in comparison with other potentially suitable datasets. Despite it being one of the simpler datasets to obtain, I received the data several months after my first request. For these reasons, as well as the costs associated with obtaining an LSMS dataset, it was not possible to use a second LSMS for comparative purposes in this thesis. I did, however, think it was desirable to have some comparative analyses of some of the key points of the thesis. Malawi is a very poor low-income country, with a very low human development index[252]; the properties of the wealth index are likely to differ considerably across settings, and particularly between countries at different levels of development. For this reason, limited re-analysis was conducted in the Brazil DHS. This dataset does not contain consumption expenditure data, so was only used for issues surrounding wealth index construction as it is performed with DHS data.

Whilst no two datasets would have provided the perfect comparison, the limitations of the chosen datasets must be recognised. Malawi and Brazil differ not only in their stage of development; Malawi is a sub-Saharan African country whilst Brazil is in South America, and Malawi is a small relatively homogenous country whilst Brazil is very large and heterogenous. All of these factors may affect any differences observed between Malawi and Brazil.

2.2 The Malawi Integrated Household Survey 2004/2005

2.2.1 Malawi: Country Profile

The Republic of Malawi gained independence from Britain in 1964. It is a land-locked country in South-Eastern Africa. It borders Zambia, Tanzania, and Mozambique. Malawi has a population of over 13 million, and is one of the more population-dense countries of Sub-Saharan Africa. Malawi was ranked 164th out of 177 countries in the 2005 Human Development Index. In 2006 its GDP per capita (PPP) was US$596 and life expectancy is less than 50 for both men and women. The under-5 mortality rate is high at 120 per 1000, as is the HIV prevalence rate, which is estimated at over 14% of adults aged 15-49 years.[252]

The majority of Malawians are subsistence farmers. In the IHS2, 56.2% of household heads are farmers working mainly their own or their family's land, 17.1% are employees, 5.4% are family business workers, and the remainder are unemployed, homemakers, students, or other. Many people engage in casual labour (ganyu). In rural areas, this often takes the form of temporary work on larger land-owners' farms at busy times in the agricultural land. Payment for this casual labour may be either in cash or in food or other goods. Agricultural activities vary by season and region in Malawi. A detailed picture of the regional differences in livelihoods is provided in the Malawi Livelihoods Profile carried out by the Malawi National Vulnerability Assessment Committtee.[253] Higher altitude areas tend to be cooler, with higher rainfall and better crop potential. Generally, soil conditions are favourable in the highland areas of the Southern region, compared with highland areas of the Northern region, meaning that these areas have a higher proportion of households that are food self-sufficient. The Southern region also contains the country's biggest urban population, which further improves the livelihoods of the rural population in the South through increased market potential and employment opportunities. The range of crops grown in the South is also higher, and the dependence on maize as the main staple food is lower. The Central region tends to fall in between the Northern and Southern regions in terms of population, ecology, and agricultural activity. Trade crops differ between regions; tobacco is grown in the Northern and Central regions, and cotton is grown in the Southern region. There are some areas with distinct characteristics; e.g. most households in the Southern Lakeshore Zone generate their main income through fishing, and the Thyolo Mulanje Tea Estate Zone contains tea smallholders and estate workers. Malawi has two main seasons; a rainy season between December and March, a dry season from April to November. Weather varies with altitude, which is very variable across Malawi. Harvesting of crops usually occurs some time into the dry season, meaning that there is sometimes a 'hungry season' just after the rains when the previous harvest's crops are depleted but the new crop is not yet ready.

Malawi is one of the least urbanised countries in Africa, with approximately 20% of the population living in urban areas. Despite its current low urban population, Malawi has one of the fastest urbanisation rates in the world, at 6.3% per annum; over three times the global rate and over twice the average rate for Africa. This rapid urbanisation is not accompanied by equal rates of economic growth, and as such urban poverty continues to increase. In 2005, approximately 90% of urban residents were estimated to be slum dwellers.[254]

2.2.2 Survey information

The Malawi Integrated Household Survey 2004/2005 (IHS2) was conducted between March 2004 and March 2005 by the National Statistics Office of Malawi, with technical assistance from the World Bank. The aim of the study was to collect detailed information on poverty in Malawi in order to inform policy, and to compare with a previous study carried out in 1997-98. The study topics cover a broad range of policy issues, including income, employment, health, and education.

The study is part of the Living Standards Measurement Studies (LSMS). LSMS is a World Bank initiative, designed to improve the quality of living standards data collected by government statistical offices in low-income countries.[251] The World Bank has provided assistance to a range of countries, helping to design and carry out policy-relevant surveys. Survey methodology is adapted to meet the needs of each specific country, but some key features are common to all or most of the datasets. By and large, the studies are large and nationally-representative. They usually feature detailed consumption expenditure data, as well as a wide range of other living standards measures, including the assets and public services commonly used to construct a wealth index. They also generally include some health data, including anthropometrics for children.

Details of the IHS2 can be found in the Basic Information Document prepared by the National Statistics Office of Malawi.[255] The IHS2 survey used both household and community questionnaires. In the household questionnaire, some data are collected from all household members, and some modules are completed on behalf of the household by the household-head (as defined by the household members themselves). Data are collected on a variety of topics, including household characteristics, education, health, time use, housing, consumption, durable goods, agriculture, and so on. Anthropometry data are collected from all children aged between six and 60 months.

A community questionnaire was completed for each enumeration area (EA) included in the sample; a panel of several knowledgeable local residents (e.g. chiefs, politicians, village elders, school headmaster, religious leader, health workers, long-term residents, and so on) were brought together to complete the questionnaire by consensus. Since an EA is defined for administrative purposes and may not represent what residents consider to be their community, the questionnaire was completed in one rural village or urban location surrounding the EA, which most residents recognise as their community and is judged by the survey team to be representative of the EA. Information was collected on community characteristics, access to services, economic activities, agriculture, changes in the past five years, and prices. In order to validate the community questionnaire to some extent, I compared community-level aggregates of the main materials used for dwelling walls and roofs with the 'most commonly used' materials reported in the community questionnaire; in almost all cases the household- and community-level data matched well.

Permission to use the data was obtained from the National Statistics Office of Malawi, and the data were then obtained from the LSMS Office of the World Bank.

2.2.3 Sampling

A census from 1998 was used as the initial sampling frame for IHS2. Sampling was performed using a two-stage stratified process. Initially, the country was divided into urban and rural areas. The urban areas were the four major cities; Lilongwe, Blantyre, Mzuzu, and the Municipality of Zomba. All other areas were considered rural. Urban and rural areas were then divided into strata, based on geographical regions. Within each stratum, a list of the census enumeration areas (EAs) from the

1998 census was made. The EAs form the primary sampling units (PSUs) and were randomly selected within strata on the basis of probability proportional to size, based on population sizes in the 1998 census. Once the EAs had been selected, a household listing exercise was performed in each included EA to obtain the sampling frame for household selection. Twenty households were randomly sampled in each of the 564 EAs to make a total sample size of 11,280 households. In each EA, five replacement households were also selected to be used in case original households could not be included for any reason. In total, 504 households were replaced, mainly because no household member could be located or because the household appeared to be uninhabited. The refusal rate was low, at 43 households. Data were collected on all household members in the 11,280 households, giving a total sample size of 52,709 individuals.

Each household within an EA has the same probability of selection, but because the EAs have different numbers of households, this probability varies between EAs. The sample is therefore designed to be nationally-representative, but for unbiased estimation adjustments must be made due to clustering within the strata and unequal probability of household selection between EAs.

2.2.4 Key household-level variables and data features

In this section I provide details on some of the key variables relevant to this thesis. Other variables will be introduced and explained in the Methods sections of each chapter where they are used.

2.2.4.1 Wealth index indicators

All of the indicators commonly used to create a wealth index are contained in IHS2, i.e. presence of a domestic servant, ownership of agricultural land, toilet facility, main drinking water source, main cooking fuel, main floor material, electricity, radio, bicycle, television, motorbike, and car.

Presence of a domestic servant is identified through the household listing, which identified each household member's relationship to the household head. A new variable indicating the household-level presence or absence of a domestic servant was created by collapsing and recoding the question on relationships to the household head.

Details of land owned by the household was collected from each household head, including number, area, and type of plots. The wealth index used a variable coded as either none or some land owned.

Information about ownership of consumer durables, housing characteristics, and access to services was obtained from the household head. For each durable asset, the household head was asked whether the household owns the item; quality or functioning was not asked. Number of items owned, the age of the item, and the anticipated sale value were asked. This information was used for the consumption expenditure aggregate, but not for the wealth index.

For categorical indicators such as water source, cooking fuel, etc., interviewers had a list of options and provided details of responses that did not fit in with the pre-defined categories. For water source, the reference period is one month; other variables did not have a reference period. Categorical variables were used as a series of dummy indicators, all coded 0 or 1.

Levels of missing data were very low; no more than 0.1% for any of the indicators (**Table 2.1**). Some categories of water source, toilet facility, cooking fuel and floor material were grouped in order to prevent some groups having very low numbers. Decisions about groupings were made by examining the patterns of consumption expenditure and education across the original categories, and by ensuring that new categories 'made sense' in a subjective way. For the 'other' categories, detailed responses were also examined to get a sense of what this category represents in each case. The prevalence of each indicator is presented in **Table 2.1**.

Table 2.1: Prevalence and missing data of wealth index indicators

Indicator	*Prevalence (%)*	*% Missing*
Drinking water source		
Piped into dwelling	2.3	0.053
Piped outside dwelling	3.0	
Communal standpipe	16.9	
Personal handpipe/well	3.1	
Communal handpipe/well	67.2	
River/spring/lake/reservoir/other	7.6	
Toilet facility		
Flush toilet	2.9	0.080
VIP latrine	2.0	
Traditional latrine with roof	57.7	
Traditional latrine no roof	20.8	
None or other	16.6	
Cooking fuel		
Collected firewood	74.5	0.062
Purchased firewood	14.6	
Paraffin/gas/charcoal	7.8	
Electricity	1.8	
Crop residue/sawdust/other	1.3	
Material of dwelling floor		
Sand	2.9	0.018
Smoothed mud/other	76.6	
Smoothed cement/wood/tiles	20.5	
Electricity in the household	6.2	0.12
Television/VCR	3.9	0
Radio	54.5	0
Bicycle	36.3	0
Motorbike/scooter	0.38	0
Car	1.3	0
Domestic servant within the household	2.0	0
Household owns agricultural land	87.2	0

2.2.4.2 Consumption expenditure

I used a pre-computed consumption aggregate, prepared and provided by the National Statistics Office of Malawi. The aggregate has complete data, since median imputation had been carried out in order to compute the aggregate. Median imputation can introduce bias, since it reduces the variability of the data. The raw data, however, only have low levels of missing data (at most 0.5% missing data per indicator), so any bias introduced by the median imputation is likely to be small. Outliers had also been replaced by median values, but again examination of the raw data revealed that the prevalence of outliers was very low.

Data collection and analysis for consumption expenditure in IHS2 was guided by the recommendations of Deaton and Zaidi.[31] All expenditures are reported at the household level.

Consumption expenditures were recorded for a wide range of items that broadly fall into four categories: food, non-food non-consumer durables, consumer durables, and housing. Food consumption includes purchased and home-produced items, as well as items received as gifts or free from other sources. Examples of non-food non-consumer durables include education, entertainment, clothing, and so on. Consumer durable expenditure was estimated based on questions related to ownership, age, and expected resale value of durable items. Yearly 'use value' for each consumer durable was estimated by assuming an expected lifetime for each item, calculating the remaining lifetime, and dividing the current estimated value by the remaining lifetime. Housing costs may be actual rental costs or self-estimated rental costs. Expenditures related to business activities or income-generating assets were not included. Expenditures related to repairs of dwellings were excluded, since these should be reflected in actual or estimated rent.

All food items have a recall period of seven days; the recall period for non-food items depended on the expected purchasing frequency. Items such as fuels and public transport had a one-week recall period; a one-month period was used for less frequent expenditures such as toiletries, mortgage or rent payments, household and vehicle repairs, and household cleaning products; a three-month reference period was used for items such as clothes, shoes, books, house decoration, cooking or cleaning utensils, cloth and sewing items, etc, and a 12-month recall period was used for rarer expenditures such as carpets, linen, mosquito nets, insurance, legal fees, thatching, and so on.

For all food items, respondents were asked to report the total quantity consumed, how much of the food was purchased, how much was home-produced, and how much was received from gifts or other sources. For purchased goods, expenditure in Malawi Kwachi was reported. The quantities of home-produced and received foods were then used to impute a value using an appropriate unit price. The unit price was generally the median product price over households purchasing the item in that geographical area at that time of year. A minimum of seven households was used to generate the unit price; the area and/or time frame was expanded if necessary to base the price on at least seven households. Expenditure data were collected from the household head and/or the individual household member most responsible for expenditures of that specific nature.

The aggregated consumption expenditure measure is calculated by annualising all recall periods and summing the expenditures (adjusted for price differences across areas). Consumption expenditure is generally adjusted for household size and composition using an equivalence scale. For the majority of analyses in this thesis, I used a per capita expenditure measure, i.e. total expenditures divided by the total household size.

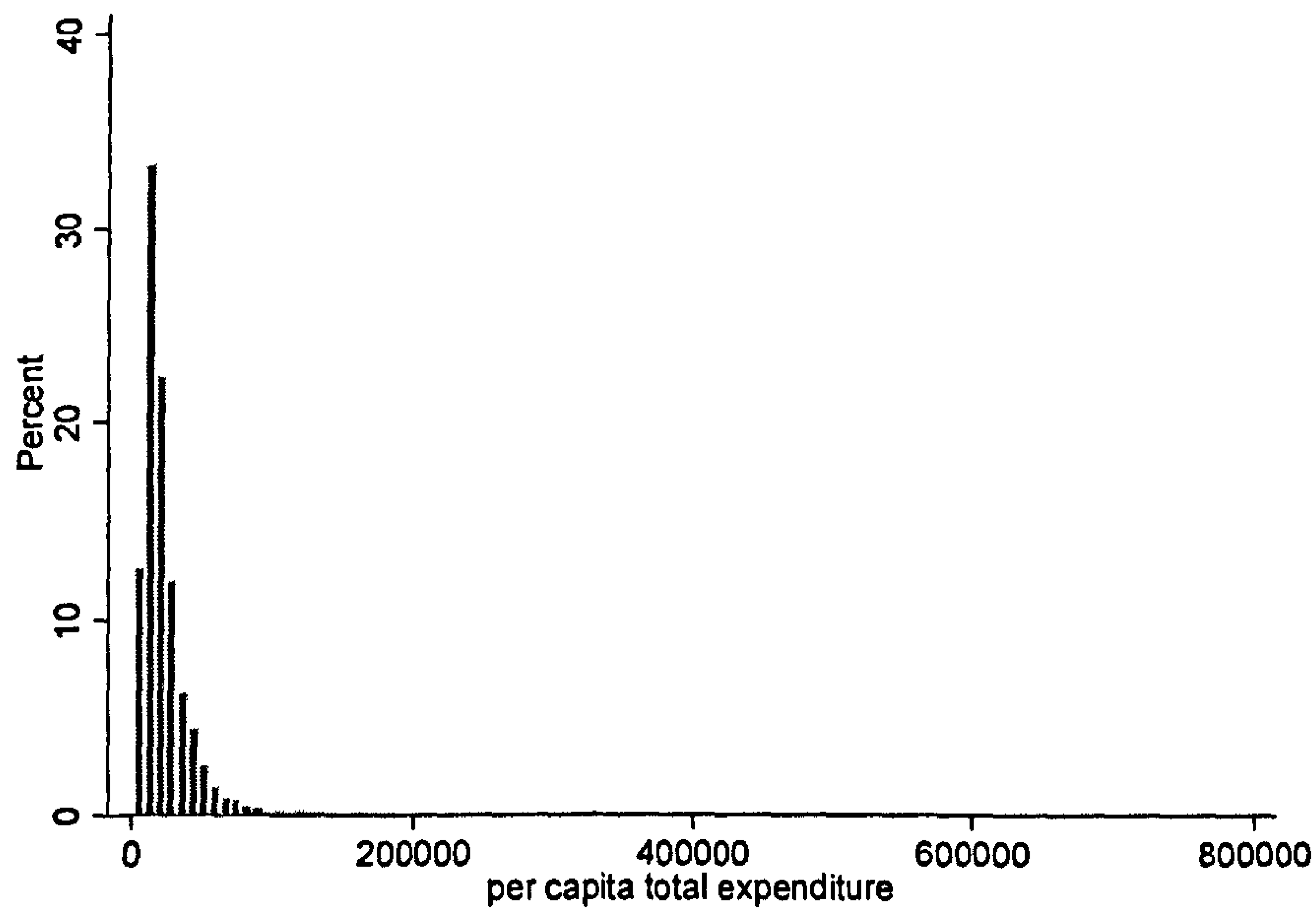
Descriptive statistics of per capita consumption expenditure are provided in **Figure 2.1**. The aggregate measure has a mean of 24709 Malawi Kwacha (very approximately US$200), a standard deviation of 27865 Kwacha, and a very right-skewed distribution, with total values ranging from 1,424.8 to 765,641.2 Kwacha. The median per capita expenditure is 17,823.5 Kwacha. The distribution differs markedly across areas, with the mean and all percentiles being lowest in rural areas, highest in urban areas (defined as the major urban centres of Blantyre, Lilongwe, Zomba, and Mzuzu), with peri-urban areas (defined as large or small urban centres, bomas, and gazetted townships) being intermediate.

The survey was conduced over a 13-month period, between March 2004 – March 2005. Interviews were fairly evenly spread across these months, with between 545 and 1,141 interviews conducted in each month. Interviews were conducted simultaneously across the regions of Malawi, so within each region there is a roughly even spread of interviews across the time period of data collection. In all regions, slightly fewer interviews were conducted in the rainy season months of December to March. Since agricultural activity, and hence food consumption, vary across the year, the wide spread of interview dates could have affected the measurement of consumption expenditure. Although many LSMS surveys attempt to minimise this source of bias by asking about a 'typical' month's consumption, this was not done in the Malawi IHS2. The recall period for all food items was the past seven days, meaning that there is likely to have been considerable differences in reported expenditures depending on the season during which the interview was conducted. This potential bias is evident in the data presented in **Figure 2.1**, which show that the reported expenditures differ substantially between months of interview, with expenditures being lower in the rainy season months of December to March. The seasonal patterns of reported consumption expenditure were similar across the three regions of Malawi (data not shown). The effect of month of interview on consumption expenditure appears to be similar to its effect on wealth index scores (**Figure 2.1**). The rankings show that those interview months with lower mean reported expenditures also tend to have lower mean wealth index scores, and vice versa. There is remarkable consistency in the ordering of interview months in terms of the mean expenditure and mean wealth index score. Since the ownership of durable goods, dwelling characteristics, etc used to construct the wealth index are unlikely to change between seasons, it can be concluded that much of the variation in expenditure scores across households interviewed in different months is not due to bias in the consumption expenditure measure introduced due to the seasonality of food production and consumption.

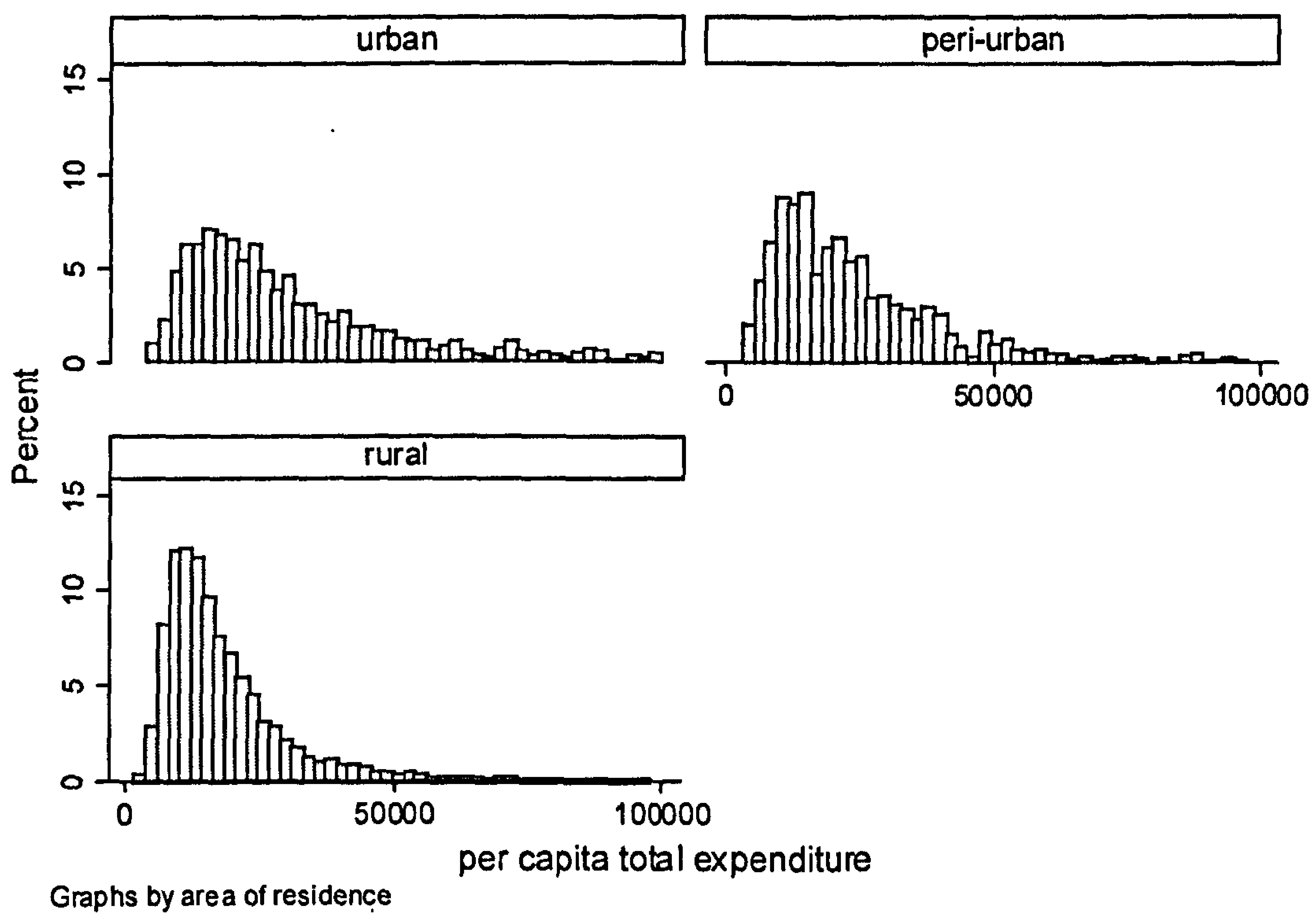
Figure 2.1: Description of per capita consumption expenditure data

A: Distribution of per capita consumption expenditure:

Whole population:



By area (excluding values of expenditure over 100,000 Kwacha):



B: Summary statistics of per capita consumption expenditure:

	Overall	*Rural areas*	*Peri-urban areas*	*Urban areas*
Mean (SD)	24,708.6 (27685.6)	20,886.9 (17,551.6)	30,297.2 (24,317.7)	45,988.1 (56521.2)
Minimum	1,424.8	1,424.8	3,736.5	4,572.4
Maximum	765,641.2	515,950.1	183,919.7	765,641.2
Percentiles				
5th	6,994.5	6,764.4	7,797.8	9,663.2
10th	84,02.3	8,107.7	9,823.5	11,890.6
25th	11,823.5	11,186.5	14,297.2	17,741.1
50th	17,856.0	16,537.6	23,244.9	28,539.4
75th	28,072.2	24,945.4	37,814.5	49,279.3
90th	44,297.3	37,996.1	57,813.0	96,340.6
95th	60,935.3	48,187.2	75,855.9	147,111.0
% Households in each quintile				
Q1	20	6.8	13.4	22.6
Q2	20	11.1	15.0	21.8
Q3	20	15.5	15.5	21.1
Q4	20	21.9	21.9	19.5
Q5	20	44.7	34.2	15.0

C: Effect of month of interview on reported expenditures:

Month of interview	*Frequency*	*Mean per capita expenditure*	*SD of per capita expenditure*
March 2004	915	27118.805	39093.061
April 2004	938	25962.934	27451.708
May 2004	825	27351.045	34302.175
June 2004	977	27911.052	35900.339
July 2004	728	26727.027	21207.871
August 2004	1141	27052.861	24097.05
September 2004	1045	23291.284	19243.128
October 2004	918	25368.713	32700.232
November 2004	770	28423.206	33570.94
December 2004	640	21784.795	18378.654
January 2005	545	19933.51	14756.929
February 2005	896	18343.17	15357.247
March 2005	942	19780.131	21242.734

ANOVA of monthly differences: $p<0.001$

D: Comparative effect of month of interview on consumption expenditure and the wealth index (rankings show, from lowest to highest, the order of mean expenditure/wealth index score by month of interview):

Month of interview	*Mean per capita expenditure*	*Rank*	*Mean wealth index score*	*Rank*
March 2004	27118.805	10	.01658255	10
April 2004	25962.934	7	.06989844	12
May 2004	27351.045	11	.00443561	9
June 2004	27911.052	12	.01984733	11
July 2004	26727.027	8	-0.04167553	6
August 2004	27052.861	9	-0.08934147	4
September 2004	23291.284	5	-0.03833652	7
October 2004	25368.713	6	-0.03268328	8
November 2004	28423.206	13	.16622937	13
December 2004	21784.795	4	-0.04182038	5
January 2005	19933.51	3	-0.10539765	3
February 2005	18343.17	1	-0.1753068	1
March 2005	19780.131	2	-0.125532	2

Reliability of the consumption expenditure measure

Consumption expenditure will be used throughout this thesis as a benchmark against which to compare the wealth index. Its agreement with the wealth index will clearly be affected by its own measurement error. As discussed above, there are various problems with data collection for consumption expenditure that may have affected its reliability. Perhaps most importantly, recall may be inaccurate. It has been shown that longer recall periods tend to lead to lower reported annual expenditures[256], and that a longer list of items tends to lead to higher total reported expenditure.[257]

I have shown in **Figure 2.1**, however, that differences in food consumption according to month of interview may not be introducing substantial seasonality bias into the consumption expenditure aggregate.

2.2.4.3 Anthropometry

Anthropometry data (height/length, weight, and presence of oedema) were recorded for children aged between six and sixty months. Anthropometry measurements were taken by the field supervisor, assisted by the interviewer and the child's mother. All field staff involved in taking the measurements had received specific training. Staff were instructed to attempt to validate the child's age by asking the mother (as opposed to the household head, who provides the ages for the household listing) and by asking to see health care records or other similar official documents. Age is used to construct anthropometric indices, and having an accurate age is imperative. For length/height, children under 24 months old were measured lying down, and those aged between 24 months and 60 months were measured standing up. Length/height was recorded in centimetres, to the first decimal place. Height-for-age z-scores were computed using the Stata macro for the World Health Organisation Multi-centre Growth Reference Study (see **Section 10.3**). Stunting was defined as a height-for-age z-score of less than -2. The distribution and level of missing data for height-for-age will be detailed in **Section 10.4**.

2.2.4.4 Household composition

Household members were defined as those who normally live together and share meals. The household head was self-identified by the household member(s) interviewed by the survey team. 77% of household head's are male, and the mean age was 42.5 years (SD = 16.4 years). In multigenerational households, both grandparents and parents were named as household heads, but it was more common for the household head to be from the older generation. Household sizes ranged from 1-27 individuals (mean = 4.5, SD = 2.3). Further information about household composition can be found in the IHS2 Report.[258]

2.3 Brazil Demographic and Health Survey 1996

The Brazil 1996 Demographic and Health Survey (DHS) was used for limited re-analysis of some key issues in the thesis.

2.3.1 Brazil: country profile

The Federative Republic of Brazil is a middle-income country in South America. It is a large country, occupying roughly half the land mass of South America. It gained independence from Portugal in 1822. It has a population of over 189 million, and a diverse economy with wide variations in development level across geographical areas. It is the most economically developed country of South America. In the 2005 Human Development Index, Brazil was ranked 70th out of 177 countries. The GDP per capita (PPP) is US$11,873. Life expectancy is over 70 years, and the under-5 mortality rate in 2006 was 20.0 per 1,000 live births.[259] Over 80% of Brazil's population lives in urban areas.

2.3.2 Survey information

Demographic and Health Surveys are conducted in a range of low- and middle-income countries, using standardised processes and survey materials in order to collect reliable, comparable data on a range of population, health, and nutrition indicators. They are conducted under the guidance of the company Macro International.

In the Brazil 1996 DHS, 13,283 households were included in the nationally-representative sample. Multi-stage sampling was used. As in the Malawi IHS2, the primary sampling units were census tract areas that were identified from a list obtained from the most recent census and selected randomly using probability proportional to size. An updated household listing for each included census tract area was obtained from Instituto Brasileiro de Geografia e Estatística, Brazil's national statistics office. Within each geographical region, a constant percentage of households within each census tract area were randomly selected. This percentage differed between regions, making the probability of household selection different between regions. As such analysis needs to consider both clustering and sampling weights.

All women aged 15-49 years in selected households are eligible to be interviewed, and a sample of households were also selected for all men aged 15-49 to be interviewed, using separate male and female questionnaires. 16,838 households were selected, and questionnaires were completed for at least one household member in 13,283 households (79%). Data were collected on household characteristics, demographic indicators, health and healthcare use. The only parts of the data used in this thesis were the variables used to create the standard wealth index (which were all collected from the household head), and the urban/rural location of the household.

Household size ranged from one to 18 individuals (mean = 4.3, SD = 2.1); 80% of household heads were male.

2.3.3 Wealth index

A wealth index was constructed for the Brazil 1996 DHS, as used in the report by Gwatkin *et al.* on inequalities in the same dataset.[260] Categorical variables were kept with their original categories in order to be consisted with the previous work, but this meant several categories having very small numbers (**Table 2.2**). The wealth index was created using Principal Components Analysis (PCA) using the first principal component scores as the wealth index. Levels of missing data were very low, at less than 0.4% for each of the indicators (**Table 2.2**), and 1.1% for the final wealth index.

Table 2.2: Indicators in the Brazil 1996 DHS wealth index

Asset	*Weight from PCA*	*Prevalence (%) N=13,283*	*Missing (%)*
Has electricity	0.2540	93.8	0.15
Has radio	0.1662	87.8	0.29
Has television	0.3096	68.3	0.34
Has fridge	0.3173	78.2	0.30
Has car	0.2208	30.4	0.35
Has domestic servant	0.0252	5.8	0
Drinking water source			
Piped into dwelling	0.2471	69.3	0.068
Piped into yard/plot	-0.0930	3.5	
Well/spring inside	-0.1230	12.7	
Well/spring outside	-0.1575	8.6	
Bottled water	0.0669	3.3	
Other	-0.1200	2.7	
Toilet facility			
Toilet to sewer	0.2335	41.9	0.34
Toilet to open space	-0.0456	4.5	
Toilet to river/lake	-0.0094	1.6	
Latrine to sewer	0.0712	10.6	
Latrine not connected	0.0095	17.8	
Traditional latrine	-0.0863	13.0	
No facility	-0.2818	10.7	
Other	-0.0099	0.0075	
Material of dwelling floor			
Earth/sand	-0.2240	5.6	0.045
Wood planks	0.0017	7.2	
Polished wood	0.0837	12.0	
Vinyl	0.0310	0.76	
Ceramic tiles	0.2219	28.5	
Cemento	-0.1643	41.1	
Carpet	0.0769	4.2	
Other	-0.0182	0.71	
Wall material			
Palm/straw	-0.0627	0.26	0.068
Unpolished mud	-0.2057	3.1	
Raw wood	-0.0835	2.5	
Alvanaria	0.1922	85.1	
Polished wood	-0.0488	9.0	
Other	-0.0100	0.0017	
Roof material			
Palm/straw	-0.1367	1.3	0.045
Raw wood	-0.0191	0.42	
Clay tiles	-0.2102	49.8	
Concrete	0.2634	32.4	
Zinc	-0.0402	2.9	
Polished wood	0.0628	9.8	
Eternit/Amianto	-0.0137	3.0	
Other	-0.0226	0.43	
Persons per sleeping room	-0.1114	[mean=2.18, SE=0.0094]	0.060

2.4 *Statistical analysis*

Prior to analysis, data were checked and cleaned. Datasets for individual questionnaires/modules were merged as appropriate. Data checks included range and consistency checks, creation of new variables, missing data checks, creation of unique identification numbers for individuals, and so on.

All data cleaning and analyses were performed in Stata 10.0[261], apart from path analysis (**Chapters 8 & 9**), which was performed in Mplus version 5.[262] Detailed analysis descriptions will be provided in each chapter. The main feature common to all analyses is that wherever possible, account was taken of the clustering induced by the sampling framework, and household weights were used based on the probability of selection in each EA. The survey commands in Stata were used for tabulations, estimating the mean, and regressions unless otherwise specified in the methods sections of each chapter.

Part II: What is the relationship between the wealth index and consumption expenditure?

3. Is the wealth index a proxy for consumption expenditure? A systematic review

In this section of the thesis, I explore the first of my three main research questions: what is the relationship between the wealth index and consumption expenditure?

This chapter poses the question of whether the wealth index is a proxy for consumption expenditure, and begins to explore this question through a systematic review of the literature. Many economists view consumption expenditure as the preferred measure of 'permanent income' in low-income countries because of both difficulties in measuring income in these settings and the tendency of households to smooth consumption in response to short-term fluctuations in income. Some advocates of the wealth index view it as a simple proxy for consumption expenditure, which is complex and costly to collect and analyse. Others, however, either question the ability of a wealth index to proxy consumption expenditure, or view the wealth index as measuring a different underlying concept.

3.1 The wealth index as a proxy for consumption expenditure

Some proponents view the wealth index as a simplified proxy for consumption expenditure.[29, 58, 263] Asset ownership is likely to be based at least partially on economic position, and household assets are unlikely to change in response to short-term economic shocks, so asset ownership could be considered a measure of long-term economic position similar to consumption expenditure. However, consumption expenditure data are usually collected by an established and theoretically-grounded methodology, using lengthy questionnaires with information on an extremely wide variety of expenditures. It is not clear how well a wealth index, a measure borne primarily out of convenience rather than theory and commonly relying on a small number of indicators, can act as a proxy for consumption expenditure. The main proponents of the wealth index, whilst recognising certain limitations of the approach, describe the wealth index as 'an acceptably reliable proxy for consumption and thus for economic position more generally'[58], and state that a wealth index predicts school enrolment as accurately as consumption, if not more so.[29] The evidence for the ability of a wealth index to proxy consumption expenditure is limited, and until now has not been collated in a systematic way. Despite this lack of clarity, many researchers are using the wealth index as a proxy for consumption expenditure, whether implicitly or explicitly.

3.2 *Measurement of consumption expenditure and wealth indices*

Before comparing consumption expenditure and wealth indices, it is important to note that both have their own measurement issues. Detailed guidelines for the construction of consumption aggregates have been published by Deaton and Zaidi, and some of the issues mentioned in this paragraph are discussed in more depth therein.[31] Measurement of consumption expenditure is carried out using a long list of food and non-food items with varying reference periods. In such data, there will inevitably be a degree of recall bias. Furthermore, a price index is necessary to adjust expenditures for regional differences in price. This price index will introduce a degree of error since the adjustments will be estimates, not accurate for all survey respondents. The inclusion of health expenditures in consumption aggregates is not recommended by Deaton and Zaidi, but is still done in some cases. The reason for their exclusion is that health expenditure in response to ill-health actually represents a decrease in welfare rather than the increase implied by the rise in expenditures. However, some health expenditures are preventative and discretionary and may lead to increased welfare. Durable goods require a 'use value' to be derived, whereby the benefit to the household's wealth from owning the item is estimated, since it is not the purchase of the item but its use which is relevant to welfare. This use value requires assumptions, amongst others, about the purchase and sale values at the start and end of the reference period. A use value, or rental equivalent, must also be estimated for housing. This is extremely difficult in low-income settings where rental markets may be practically non-existent. Finally, the value to be attached to home-produced goods must also be estimated. In summary, measurement of consumption expenditure requires a large set of assumptions, imputations, and estimations, and also suffers from considerable potential for recall bias.

Collection of asset data has been claimed to be more reliable than consumption expenditure data, since it uses simple questions or direct observation by the interviewer and should therefore suffer from less recall bias.[67] There is also some empirical work using instrumental variable analysis showing that models of inequality using a wealth index are estimated with less measurement error than models using consumption expenditure.[29] The reliability of asset data has, however, been questioned by a recent study in Nigeria which demonstrated at best moderate inter-observer and between-test reliability for asset data collection.[245]

3.3 The wealth index & consumption expenditure; a systematic review

3.3.1 Objectives & Hypotheses

The overall review objective is:

- To systematically review the evidence relating to the ability of the wealth index to act as a proxy for consumption expenditure

Specific objectives are:

1. Quantify the ability of a wealth index to act as a proxy for consumption expenditure
2. Where data are available, investigate the hypothesis that the level of agreement differs by setting (urban, rural) or the type and number of indicators included in the wealth index

My hypotheses are:

1. The wealth index will be a fairly weak proxy for consumption expenditure overall

2. Agreement between the wealth index and consumption expenditure may be higher in urban areas and higher income countries compared with rural areas and lower income countries

3.3.2 Methods

3.3.2.1 Search strategy

A protocol was developed following consultation with library staff about appropriate databases, and referring to several sets of guidelines on the conduct of systematic reviews.[264-266] 14 electronic databases, the World Bank website, the DHS website, and Google were searched using appropriate text words and thesaurus terms related to wealth indices and consumption expenditure as detailed in **Box 3.1**. Search terms were determined in order to attempt to capture the different terminology for wealth indices and consumption expenditure but to keep the number of irrelevant hits to a minimum. Truncation terms were used wherever relevant and possible, for example associat* was used to capture both association and associated and reliab* for both reliable and reliability. MeSH terms were used wherever possible for "social class". The titles and abstracts of hits from databases were screened for potential relevance. Where potential relevance could not be determined from the abstract, the full paper was reviewed.

Studies identified as potentially relevant from the initial screen were reviewed independently by myself and a second reviewer[1] against pre-defined inclusion and exclusion criteria. It was not possible to conduct blind screening using only the methods sections of papers because it was not always apparent from the methods section that a relevant comparison had been made, and secondly because not all papers followed the standard format with clearly defined methods and results sections. First authors of included papers and others known to be working in the field were contacted for any unidentified or unpublished work, the Web of Knowledge was used to search for papers citing any included paper, and the

[1] Sabine Gabrysch, Epidemiology and Population Health, London School of Hygiene and Tropical Medicine

reference sections of all included papers were screened for potentially relevant papers. First authors were also contacted for further information if necessary.

Box 3.1: Databases, web-sites and search engines used for systematic review

Electronic databases	**Internet resources**
PubMed	World Bank website
Web of Knowledge	DHS Website
Ovid Embase	Google
IBSS	
Popline	
Lilacs	
Eldis	
IDS	
Zetoc	
Africa Healthline	
CAB abstracts	
NBER working papers	
Academic Search Premier	
IngentaConnect	

Search terms
poverty OR socioeconomic OR socio-economic OR economic status OR social class OR wealth OR asset
AND
indicator OR index OR measure OR proxy OR indices
AND
relationship OR correlation OR association OR validity OR reliability OR agree
AND
consumption OR expenditure OR permanent income OR income

3.3.2.2 Inclusion and exclusion criteria

All studies measuring the unadjusted relationship between household consumption expenditure and a household wealth index were included. No restrictions were placed on how consumption expenditure was measured, although this was noted as part of the assessment of study quality. A wealth index was considered to be any household-level composite index of any combination of consumer durables, indicators of access to services, housing characteristics or any other factors potentially relevant to socio-economic position. Studies were excluded if a consumption expenditure aggregate formed part of the wealth index, as this would not be relevant to the notion of a wealth index being a simplified proxy for consumption expenditure. No restrictions were placed on the measure of agreement between the consumption expenditure measure and the wealth index, although studies only comparing the approaches on the basis of observed inequalities by the two methods and not making any direct comparison were excluded. Studies were not excluded on the basis of methodological limitations, but these were documented. No restrictions were placed on geographical location, date or language of publication.

3.3.2.3 Analysis strategy

I identified all datasets used in the included studies. Some studies selected for inclusion reported results for more than one dataset, whilst some datasets were represented in more than one study. Furthermore, in some cases i) more than one measure of agreement between the wealth index and consumption expenditure was presented, and/or ii) more than one method for constructing or weighting the wealth index was applied. Results were selected for the whole population if available, or results stratified by area were used if no aggregated results were presented. Thus for each dataset, a single measure of agreement was selected using the following rules:

1. Select measures of agreement within the entire population if these are available. If results were only available separately for sub-populations (e.g. urban and rural), include all available sub-populations
2. Select the measure of agreement with the most appropriate measure (see below)
3. If there are multiple estimates using the same measure of agreement from the same dataset, the strongest association was chosen since my primary hypothesis was that level of agreement would be low.

Choosing the most appropriate measure of agreement

Measures of agreement were selected using the following order of preference:

i. Overall agreement/misclassification between three or more groups of the wealth index and three or more groups of consumption expenditure, with groups based on percentiles. If there are multiple specifications of groups for one dataset, select the specification with the greater number of groups.

ii. Correspondence index (explained below).

iii. R^2 values of regression on consumption expenditure.

iv. Correlation coefficient.

v. Agreement/misclassification/sensitivity etc between two groups of the wealth index and two groups of consumption expenditure, e.g. poor/non-poor.

vi. Agreement/misclassification between three or more groups of the wealth index and three or more groups of consumption expenditure, with groups based on percentiles but agreement not available as an aggregate for all groups.

Agreement of classification was chosen as the prefered measure because of its transparency, ease of interpretation, and relevance to the most common way of using wealth indices, i.e. division into quantiles.

Sahn and Stifel[67] used correspondence indices to assess agreement between deciles of the wealth index and deciles of consumption expenditure. The correspondence index is calculated as follows:

$$C = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(i-j)^2 m_{ij}}{2\sum_{i=1}^{n/2}(i-n)^2} \times \frac{1}{0.322'}$$

where: n is an even number of quantiles (ten in the work by Sahn and Stifel), i and j are the row and column quantile respectively, m_{ij} is the transition share associated with ij-th cell of the transition matrix. The measure only gives weights to the off-diagonal elements of the cross-tabulation, i.e. to households classified differentially. The weights increase as the distance from the diagonal increases. A zero value indicates perfect correspondence, i.e. no differential classification. A value of one indicates perfect random association between the two distributions.

I grouped the selected measures of agreement by those showing strong, moderate, or weak agreement and then counted the number of datasets demonstrating each level of agreement. Definitions of these three groups for each measure of agreement are provided in **Table 3.1**. There is no universal consensus on acceptable levels of any of the measures of agreement used. Therefore I determined the cut-off points based on subjective views of the acceptable strength of relationship for a reliable proxy measure. Given that the aim of this study was to assess the ability of the wealth index to proxy consumption expenditure, rather than merely evaluating the association between the two, I selected relatively conservative cut-off points. Where measures of both sensitivity and specificity were presented, sensitivity was selected, i.e. proportion of those below an expenditure-based poverty line correctly identified, since this is arguably the most important outcome if a wealth index is to be used for program targeting. I used a higher threshold for sensitivity than for classification into three or more percentile groups, since a higher degree of agreement can be expected when using a cruder poor/non-poor classification. Meta analysis of the level of agreement between the wealth index and consumption expenditure was not possible due to the different methods of summarising agreement used in each of the included studies.

Further analyses were conducted to examine the effect on agreement i) when different types and numbers of indicators are used to construct the wealth index, ii) in different settings, and iii) when different consumption equivalence scales are used.

Table 3.1: Assessment of the strength of agreement

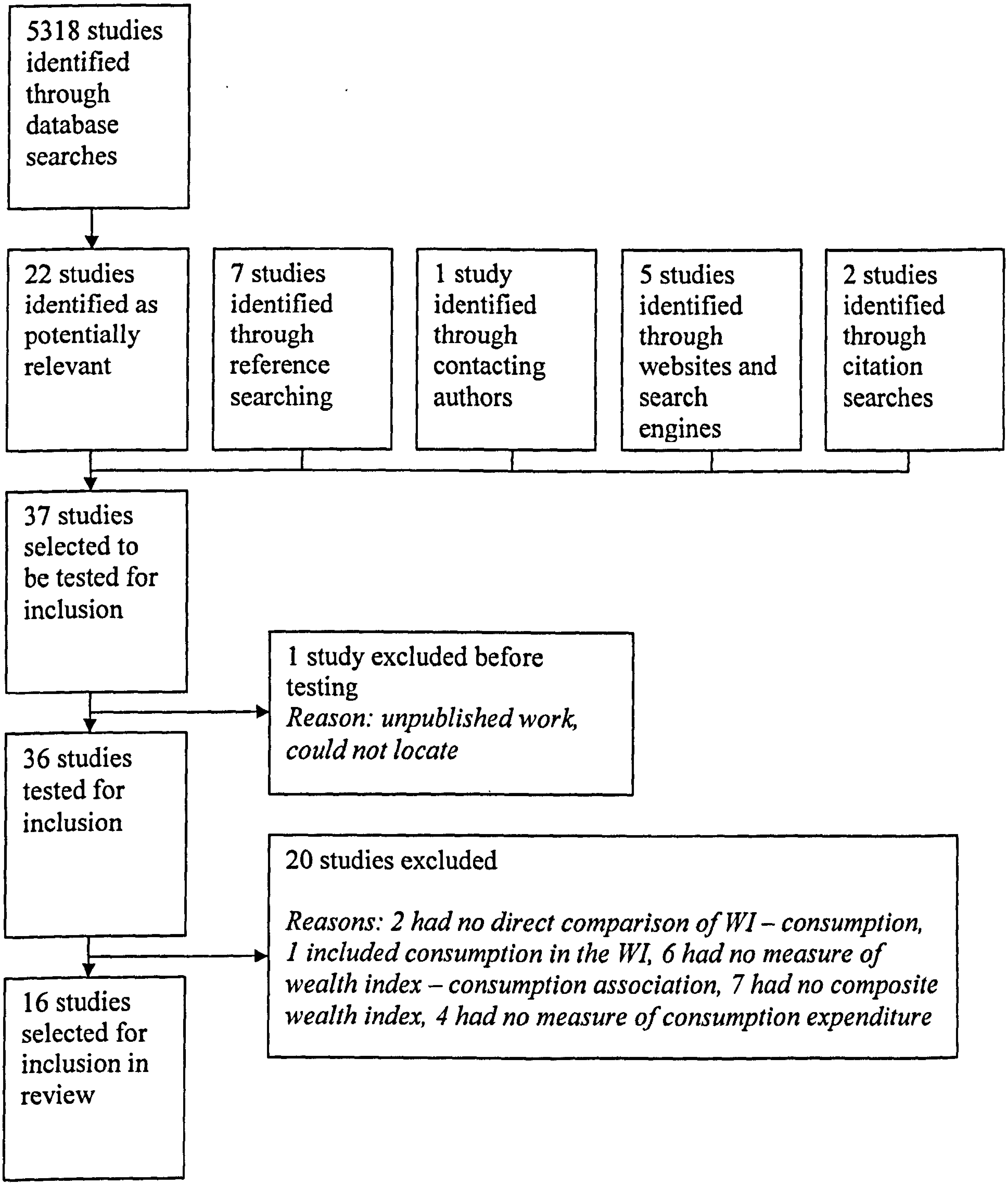
Measure of agreement	***Strength of agreement***		
	Strong	*Moderate*	*Weak*
Agreement of classification into quantiles	>75% correctly classified	60-75% correctly classified	<60% correctly classified
Correspondence index	0-0.25	0.25-0.45	>0.45
R^2 values from regression	0.49-1.0	0.25-0.49	<0.25
Correlation coefficients	0.7-1.0	0.5-0.7	<0.5
Sensitivity	>80%	65-80%	<65%

3.3.3 Results

3.3.3.1 Selection of studies

Database searches (carried out earlier and updated on 6th March 2008) identified 5,318 abstracts and titles which were reviewed for potential relevance. The process of study selection is shown in **Figure 3.1**. Of the 36 studies tested for inclusion, 16 were included in the final review. Six studies were excluded because they had no measure of the association between the wealth index and consumption expenditure.[32, 94, 267-270] Four studies were excluded because they had no measure of consumption expenditure.[245, 271-273] Seven studies were excluded because they had no composite wealth index.[274-280] One study was excluded because a consumption expenditure aggregate was included in the wealth index.[281] A further two studies were excluded because there were no direct comparisons between the wealth index and consumption expenditure; the relationship was assessed by the difference in inequalities only.[63, 192]

Figure 3.1: Selection of studies for systematic review



The detailed results from the systematic review, including the study characteristics, details of wealth index measurement, methodological limitations of included studies, and so on are presented in **Table 3.2**. All studies were from low- and middle-income countries, and datasets come from a range of countries from various geographical regions and with differing economic conditions. Datasets used were generally large, nationally-representative surveys, apart from two studies that used data from rural areas only[282, 283] (n.b. Montgomery uses six datasets, all but the Guatemala data are nationally-representative) and two studies that used data from restricted regions within a country.[56, 284]

Several datasets were represented in more than one study. The 1991 LSMS from Pakistan was used in four studies[29, 67, 283, 285]; Filmer and Pritchett was included in the analysis because their analysis was of agreement between percentile groups whereas Sahn and Stifel used the correspondence index and Montgomery and Ferguson both used correlation coefficients. Nepal's 1996 LSMS was used by two studies[29, 286]; Filmer and Pritchett's analysis was included in the review because it had data for agreement across all groups whereas Filmer and Scott only present agreement for households in the lowest quintile of expenditures. The Ghana 1988 LSMS was used by two studies[67, 286]; Sahn and Stifel's analysis was included because agreement between quintiles is available whereas Montgomery uses R^2. The 1996 LSMS from Papua New Guinea, the South Africa 1994 LSMS, and the Vietnam 1993 LSMS were all used by the same two studies[67, 286]; in each case Sahn and Stifel's analyses were included because they used the correspondence index whereas Filmer and Scott only present agreement for the lowest quintile of expenditures. Peru's 1994 LSMS was used by two studies[67, 283]; Sahn and Stifel was included in the review because they used the correspondence index rather than R^2 values used by Montgomery. Jamaica's 1989 LSMS was used by two studies[283, 287]; Grosch was included in the review because a stronger association was observed. Albania's 2002 LSMS was used by two studies[122, 286]; Azzarri's analysis was included in the review because it presents agreement across the whole population whereas Filmer and Scott present agreement only for the lowest quintile of expenditures. Two studies use the Tanzania Household Budget Survey[270, 284]; Ward's paper is included in the review because his analysis is of whole-population data whereas Setel separates urban and rural areas.

3.3.3.2 Methodological limitations of included studies

Overall the methodological quality of the studies was high. Many studies utilised LSMS datasets, which are nationally-representative and contain very detailed consumption expenditure aggregates. The most common methodological limitations of the included studies are that missing data is either not mentioned or is excluded from analyses with no discussion or exploration of the implications for results (all studies) and that the hierarchical nature of the data due to sampling methods is not discussed or addressed in analyses (11 studies). Four studies included at least one dataset that was not nationally-representative. One of the datasets used in Montgomery's paper utilised a restricted list of items to calculate the consumption expenditure aggregate, and two further non-LSMS studies provided little detail about the measurement of consumption expenditure.

Table 3.2: Full findings of systematic review
Characteristics of datasets included in the systematic review, and their agreement with consumption expenditure

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Ferguson[285]	Peru 2000 LSMS; N~4000	M, H	24	21	1	1	1			Total	Spearman's rank correlation coefficient = 0.734	STRONG
Jamal[288]	Pakistan Integrated Household Survey 2001/2 URBAN	M, U, N, H	30	17		2	8	1	2R	Total	R^2 value from regressions of indicators on consumption expenditure = 0.69	STRONG

[2] **Key to methodological limitations:** *Measurement of wealth index:* I = included narrower range of indicators than standard DHS indices; *Measurement of consumption expenditure:* L = limited details provided, C = restricted list of items; *Study design:* R = not nationally-representative; *Analysis features:* M = missing data excluded or not mentioned at all, U = analysis only performed separately for different areas, N = sample size not reported, H = clustered sampling not discussed or not taken into account in analysis

[3] **Key to indicator types:** D = consumer durables (includes all durables, domestic appliances, vehicles, telephones, etc); S = access to services (includes water supply, sanitation facilities, fuels used, healthcare use); H = housing characteristics (includes dwelling materials, ownership status, etc); C = demographics and human capital (includes education, occupation, family size and composition, crowding, etc); A = area; Other categories: P = purchases, consumption indicators, and clothing; L = livestock; R = remittances; W = subjective well-being

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Jamal[288]	Pakistan Integrated Household Survey 2001/2 RURAL	M, U, N, H	30	17		2	8	1	2R	Total	R^2 value from regressions of indicators on consumption expenditure = 0.52	STRONG
McKenzie[247]	Mexico Encuesta Nacional de Ingresos y Gastos de los Hogares 1998; N=10,773	M	27	18	4	5				Not presented	Rank correlation coefficient = 0.894	STRONG
Filmer and Scott[286]	Brazil 1996/7 LSMS; N=4940	M	29	23		6				Per capita	% households in poorest quintile of expenditures in same quintile of wealth index = 68%	MODERATE
Filmer and Scott[286]	Panama 1991 LSMS; N=4945	M	27	21	1	5				Per capita	% households in poorest quintile of expenditures in same quintile of wealth index = 72%	MODERATE

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Grosch[287]	Jamaica LSMS 1989; N~4000	M, H	24	9	3	5	6	1		Per capita	R^2 value from regressions of indicators on consumption expenditure = 0.41	MODERATE
Sahn[67]	Peru 1994 LSMS; N=3623	M	9	5	2	1	1			Per capita	Correspondence index = 0.28	MODERATE
Sahn[67]	South Africa 1994 LSMS; N=8848	M	9	5	2	1	1			Per capita	Correspondence index = 0.31	MODERATE
Sahn[67]	Vietnam 1998 LSMS; N=5999	M	9	5	2	1	1			Per capita	Correspondence index = 0.36	MODERATE
Skoufias and Coady[206]	Mexico 1998 Encuesta Nacional de Ingresos y Gastos de los Hogares RURAL; N=4378	M, U, H	20	13	5	2				Total	Sensitivity = 67.6%	MODERATE

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Sumarto[66]	Indonesia National Socioeconomic Survey 1999 URBAN	M, H, N	28	7	2	1	9		1L, 8P	Per capita	Grouped into bottom 30%, middle 40% and top 30%. 63.7% households in same group	MODERATE
Sumarto[66]	Indonesia National Socioeconomic Survey 1999 RURAL	M, H, N	31	7	4	1	10		1L, 8P	Per capita	Grouped into bottom 30%, middle 40% and top 30%. 60.1% households in same group	MODERATE
Ward[270]	Tanzanian Household Budget Survey 2000/1; N=20,883	M	26	9	1		6		10P	Per adult equivalent	% households in same tercile = 62.1%	MODERATE
Azzarri[122]	Albania 2002 LSMS; N=3600	M	13	6		1	2	1	1L, 2W	Per capita	% households in same quartile = 56.8%	WEAK

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Filmer and Pritchett[29]	Indonesia DHS 1994; N=16,242	M, H	13	6	3	4				Per adult equivalent	Classified into poorest 40%, middle 40%, and top 20%. 54.9% households in same group	WEAK
Filmer and Pritchett[29]	Pakistan Integrated Household Survey 1991 (LSMS); N=1192	M, H	15	7	4	4				Per adult equivalent	Classified into poorest 40%, middle 40%, and top 20%. 50.0% households in same group	WEAK
Filmer and Pritchett[29]	Nepal Living Standards Survey 1996 (LSMS); N=3372	M, H	16	6	4	6				Per adult equivalent	Classified into poorest 40%, middle 40%, and top 20%. 56.0% households in same group	WEAK
Filmer and Scott[286]	Nicaragua 2001 LSMS; N=4191	M	32	24	4	4				Per capita	% households in poorest quintile of expenditures in same quintile of wealth index = 56%	WEAK

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Filmer and Scott[286]	Uganda 2000 LSMS; N=10,696	M	16	9	2	5				Per capita	% households in poorest quintile of expenditures in same quintile of wealth index = 52%	WEAK
Filmer and Scott[286]	Zambia 2004 LSMS; N=19,247	M	34	26	4	4				Per capita	% households in poorest quintile of expenditures in same quintile of wealth index = 42%	WEAK
Khe[282]	Bavi District epidemiological field study; N=11,547	L, R, M, H	15	14					1L	Per capita	Sensitivity = 50.8%	WEAK
Lindelow[64]	Mozambique National Household Survey on Living Conditions; N=8250	M, H	12	7	3	2				Per capita	% households in same quintile = 25.1%	WEAK

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Montgomery[283]	Ghana 1998 LSMS; N=4291	M, H	12	6	5	1				Per adult equivalent	R^2 value from regressions of index on consumption expenditure = 0.104	WEAK
Montgomery[283]	Guatemala Encuesta de Salud Familiar 1995; N=2816	L, C, R, M, H	12	6	5	1				Per adult equivalent	R^2 value from regressions of index on consumption expenditure = 0.077	WEAK
Montgomery[283]	Tanzania 1993/4 LSMS; N=6742	M, H	10	4	5	1				Per adult equivalent	R^2 value from regressions of index on consumption expenditure = 0.155	WEAK
Rutstein[56]	Guatemala Health Demand and Expenditure Survey 1997; N=2562	L, R, M, H	13	8	3	2				Total	% households in same quintile = 36%	WEAK
Sahn[67]	Côte d'Ivoire 1988 LSMS; N=1600	M	9	5	2	1	1			Per capita	% households in same quintile = 37.0%	WEAK

Study first author	Dataset	Study Limitations[2]	Indicators included in wealth index[3]							Consumption equivalence scale	Wealth index – consumption expenditure association	Strength of agreement between wealth index and consumption expenditure
			Total	D	S	H	C	A	Other			
Sahn[67]	Ghana 1988 LSMS; N=3192	M	9	5	2	1	1			Per capita	% households in same quintile = 30.6%	WEAK
Sahn[67]	Ghana 1992 LSMS; N=4552	M	9	5	2	1	1			Per capita	% households in same quintile = 30.7%	WEAK
Sahn[67]	Jamaica 1998 LSMS; N=7375	M	9	5	2	1	1			Per capita	Correspondence index = 0.60	WEAK
Sahn[67]	Madagascar 1993 LSMS; N=4800	M	9	5	2	1	1			Per capita	Correspondence index = 0.73	WEAK
Sahn[67]	Papua New Guinea 1996 LSMS; N=1396	M	8	4	2	1	1			Per capita	Correspondence index = 0.64	WEAK
Sahn[67]	Vietnam 1993 LSMS; N=4800	M	9	5	2	1	1			Per capita	% households in same quintile = 35.5%	WEAK
Skoufias and Coady[206]	Mexico 1998 Encuesta Nacional de Ingresos y Gastos de los Hogares URBAN; N=9001	M, U, H	20	13	5	2				Per capita	Sensitivity = 53.4%	WEAK

3.3.3.3 Main findings

In total, 32 datasets were included in the review. In three studies, each with one included dataset, results were only presented for urban and rural populations separately.[66, 206, 288, 289] The number of measures of agreement included is therefore 35. Twenty-one datasets demonstrated weak agreement (60%), 10 datasets showed moderate agreement (29%), and four datasets showed strong agreement (11%) (**Table 3.3**).

Table 3.3: Summary of results of systematic review

Strength of agreement	*Number (%) of datasets*	*Mean number of indicators*	*Number %) using only durables, housing, and service indicators*	*Number (%) middle-income countries*	*Number (%) of datasets using total consumption equivalence*
Strong	4 (11%)	27.8	1 (25%)	2 (50%)	3 (75%)
Moderate	10 (29%)	21.2	3 (38%)	8 (80%)	1 (10%)
Weak	21 (60%)	14.1	12 (57%)	7 (33%)	1 (5%)

3.3.3.4 Gross misclassification

The extent of misclassification, i.e. to what extent households were classified into a non-adjacent quantile, was assessed in several of the studies, and was fairly variable. In Filmer and Scott's study, the percentage of households in the bottom 20% by expenditures that were not in the bottom 40% of the wealth index ranged from 9% in Panama to 41% in Nepal.[286]In the Guatemala dataset analysed by Rutstein *et al.* 28% of households were classified differently by more than one quintile.[56] Lindelow showed that in Mozambique National Household Survey on Living Conditions, 42.9% of households moved more than one quintile. Ward showed that in the Tanzania Household Budget Survey just 3.1% of households were classified to a non-adjacent tercile out of a total 37.9% misclassified households.[270] Filmer and Pritchett showed that the percentage of households classified into the extreme different group (i.e. bottom 40% to top 20% or vice versa) was 3.9% in Indonesia, 5.6% in Pakistan, 4.5% in Nepal.[29]

3.3.3.5 Number and type of indicators included in the wealth index

The mean number of indicators in the wealth index is highest in those datasets demonstrating strong agreement between the wealth index and consumption expenditure, intermediate in those demonstrating moderate agreement, and lowest in those demonstrating weak agreement (**Table 3.2**). This provides some evidence that a higher number of indicators in a wealth index improves its ability to act as a proxy for consumption expenditure. Further evidence to support this hypothesis is found in those studies using multiple sets of indicators to construct wealth indices. Ward's study in Tanzania found that adding groups of five, ten, fifteen, and twenty variables to a core set of indicators increased the observed agreement of the index with consumption expenditure.[270] The gains were not, however, substantial; for each additional five variables included the proportion of households classified in the same tercile only increased by approximately one percent. Grosch also demonstrated that reducing the number of indicators in the model reduced the R^2 value, although again the differences were modest.[287]

The proportion of wealth indices that included indicators other than consumer durables, housing characteristics, and access to services was highest in the datasets showing strong agreement between the wealth index and consumption expenditure, intermediate in those showing moderate agreement, and lowest in those showing weak agreement (**Table 3.2**). This provides some evidence that including a broader range of indicator types, such as demographics, human capital indicators, livestock, and so on, can improve the ability of the wealth index to act as a proxy for consumption expenditure.

Comparisons of multiple wealth indices using different indicators from the same dataset provide some evidence that it is consumer durables that make the highest contribution towards the ability of a wealth index to act as a proxy for consumption expenditure. Khe's study in Vietnam constructed separate indices for housing indicators and durable assets.[282] The sensitivity of the durable asset score with respect to consumption expenditure was considerably higher than that for the housing score; the values were 50.8% and 32.7% respectively. McKenzie created separate indices for housing indicators, utilities/service access, durable assets, as well as an index with all types of indicators.[247] The rank correlation coefficients were 0.598 for the housing index, 0.798 for the utilities index, 0.843 for the durable assets index, and 0.847 for the overall index. The highest correlation with consumption expenditure was with the overall index, but it is noteworthy that the durable assets index has a very similar correlation coefficient to the overall index, indicating that in this context the addition of housing and utilities indicators does little to improve the agreement of the wealth index with consumption expenditure. Filmer and Scott also compared indices using durable assets only with indices additionally including housing and services indicators, and also found strikingly similar agreement in each of the datasets they examined.[286]

3.3.3.6 Setting

The proportion of datasets that are from middle-income countries (according to the World Bank classification) is considerably lower in those datasets demonstrating weak agreement between the wealth index and consumption expenditure, as compared to those demonstrating strong or moderate agreement (**Table 3.2**). It is also interesting to note that the two datasets that demonstrate strong agreement that are from a low-income country are both from Pakistan, whose Gross National Income per capita is close to the cut-off between low- and middle-income countries. Of the two datasets demonstrating moderate agreement that are from low-income countries, one is from Vietnam and the other from Tanzania; Vietnam is also reasonably close to the cut-off between low- and middle-income countries. There is thus some evidence that a wealth index is a better proxy for consumption expenditure in middle-income countries compared with low-income countries.

There is also some evidence from within-dataset comparisons that a wealth index is a better proxy for consumption expenditure in urban areas compared with rural areas (**Table 3.4**). In five of the eight datasets that present agreement separately for urban and rural areas, the agreement between consumption expenditure and the wealth index is stronger in urban areas than in rural areas.

Table 3.4: Wealth indices created separately for different areas within a dataset using the same set of indicators

Study	*Dataset*	*WI-Consumption association*
Jamal[288]	Pakistan Integrated Household Survey 2001/2	R^2 values from regressions of indices on consumption expenditure: *Urban:* 0.69 *Rural:* 0.52
Lindelow[64]	Mozambique National Household Survey on Living Conditions	Re-ranking: urban households ranked higher by wealth index than consumption expenditures, vice versa for rural households. Poorer, more remote areas also lose rank even after controlling for urban/rural residence.
Montgomery[283]	Ghana 1988 (LSMS)	R^2 values from regressions of indices on consumption expenditure: *Whole population:* 0.104 *Urban:* 0.082 *Rural:* 0.014
Montgomery[283]	Jamaica 1989 (LSMS)	R^2 values from regressions of indices on consumption expenditure: *Whole population:* 0.143 *Urban:* 0.094 *Rural:* 0.106
Montgomery[283]	Pakistan 1991 (LSMS)	R^2 values from regressions of indices on consumption expenditure: *Whole population:* 0.030 *Urban:* 0.036 *Rural:* 0.025
Montgomery[283]	Peru 1994 (LSMS)	R^2 values from regressions of indices on consumption expenditure: *Whole population:* 0.154 *Urban:* 0.108 *Rural:* 0.132
Montgomery[283]	Tanzania 1993/4 (LSMS)	R^2 values from regressions of indices on consumption expenditure: Whole population: 0.155 *Urban:* 0.114 *Rural:* 0.017
Skoufias[206]	Mexico 1996 ENIGH	Sensitivity: *Urban: 53.4%* *Rural: 67.6%*
Ward 2002[270]	Tanzanian Household Budget Survey 2000/01	% households in correct tercile: *Dar es Salaam:* 60.4% *Urban:* 63.5% *Rural:* 58.6%

3.3.3.7 Consumption equivalence scales

It is argued that the benefits of items commonly included in a wealth index are at the household level, and therefore that adjustments for household size and composition are unnecessary and inappropriate.[56] Consumption expenditure is, however, usually adjusted for household size and composition, although the preferable equivalence scale is debateable.[31] Sahn and Stifel proposed that a wealth index should best approximate total household consumption expenditure, with intermediate agreement with per adult (equivalent) expenditure and lowest agreement with per capita expenditure.[67] This review supports this theory. Of the datasets showing strong agreement between the wealth index and consumption expenditure, 75% used total consumption expenditure (**Table 3.2**). This percentage reduces to 10% amongst the datasets demonstrating moderate agreement, and 5% amongst those demonstrating weak agreement. In the one dataset demonstrating strong agreement, it was not possible to discern the consumption equivalence scale used.[247]

Filmer and Scott conducted analyses to compare alternative expenditure equivalence scales and their impact on the correlation of the wealth index with consumption expenditure.[286] They divide total expenditures by the number of household members (children and adults), with the number of household members raised to the power of θ. The value of θ is varied between zero and one, such that $\theta=0$ represents total household expenditures, and $\theta=1$ represents per capita expenditures. The relationship observed in each of the 11 datasets they explore is an inverse U-shape, with lowest correlations between the wealth index and consumption expenditure when θ is zero or one, and highest correlations when θ is between 0.3-0.8. This finding therefore contrasts the view of Sahn and Stifel and the evidence from this review that total expenditures is likely to have the strongest relationship with a wealth index.

3.3.3.8 Different weighting methods for the wealth index

A variety of different weighting methods were used to construct the indices – simple sum of the number of indicators, PCA, factor analysis, and predictions based on regression modelling. Regression methods are a special case because they can be used to identify a set of indicators that are strongly predictive of consumption expenditure. This method therefore has the potential to produce a stronger association with expenditures than methods which select indicators by non-statistical means, but can clearly only be applied when a recent dataset containing both consumption expenditure and a wide range of potential wealth indicators exists for the setting of interest. Nine of the datasets included in the review used regression methods to assess the agreement between the wealth index and expenditures. However, some of these analyses pre-selected wealth indicators, for example to be consistent with previous studies. Three datasets use a range of sets of indicators to identify the best predictors of consumption expenditure.[66, 270, 287] All of these three datasets demonstrate moderate agreement between the final wealth indicators and consumption expenditure. Therefore the consumption correlates approach appears to be able to produce stronger than average agreement with expenditure, but it is possible to achieve strong agreement without using this approach.

Several studies included multiple weighting methods applied to the same set of indicators, as shown in **Table 3.5**. It is therefore possible to explore the impact of the various weighting methods on the agreement between the wealth index and consumption expenditure. In general, there appears to be little difference between the weighting methods in terms of the agreement between the resultant wealth indices and consumption expenditure. PCA produces very similar results to a simple sum index in one study[284] and to regression models in another.[247] In comparison with the latent variable HOPIT approach, a PCA-based index agreed more strongly with consumption expenditure in one setting and less strongly in another.[285] Filmer and Scott compared regression, simple sum, share weighted average[4], and PCA methods – results were

[4] Each indicator is weighted by the share of the population that does not own the asset

generally very similar, although the regression method did have slightly higher agreement on average.[286]

3.3.3.9 Other factors that may affect the association between a wealth index and consumption expenditure

Filmer and Scott explored other possible factors that could explain the differences in agreement between wealth indices and consumption expenditure across settings.[286] They observed that across their 11 datasets, there was a weak positive relationship between the variance of consumption expenditure and the correlation between the wealth index and consumption expenditure, i.e. in a setting with more unequal consumption expenditure across the population, the correlation between the wealth index and consumption expenditure tends to be higher. Filmer and Scott also show that there is a weak positive relationship between the proportion of total variance in the indicators captured by the first principal component and the correlation between the wealth index and consumption expenditure. The authors also found that the correlation between the wealth index and consumption expenditure was better in settings with low levels of extreme absolute poverty (proportion of people living on less than US$1 a day), but concluded that this is not a major determinant of the strength of the relationship.

Table 3.5: Different weighting methods applied to the same set of indicators in the same dataset, and the observed associations with consumption expenditure

First author	*Dataset*	*WI-Consumption agreement*
Ferguson		Spearman's rank correlation coefficients *Peru LSMS, 2000:* PCA – 0.734 HOPIT[5] – 0.707 *Pakistan LSMS, 1991:* PCA – 0.426 HOPIT – 0.591
Setel	Tanzania HBS 2000/1	% households in same quintile *Dar es Salaam:* PCA – 27.4% Simple sum – 26.1% *Kilimanjaro:* PCA – 29.2% Simple sum – 29.4% *Morogoro:* PCA – 29.0% Simple sum – 28.8%
McKenzie	Mexico 1998	Rank order correlation coefficients PCA – 0.847 Regression model[6] – 0.894

[5] HOPIT = hierarchical ordered probit model; a latent variable approach, which produces indicator-specific cut-off points on a latent scale representing permanent income. The cut-off points are the values of permanent income above which households are more likely to possess the asset/characteristic than not.

First author	*Dataset*	*WI-Consumption agreement*
Filmer and Scott		Proportion of households in the poorest quintile of expenditures who are also in the poorest quintile of wealth index *Albania:* Regression model – 0.47 PCA – 0.42 Share weighted average – 0.37 Simple sum – 0.38 *Brazil:* Regression model – 0.68 PCA – 0.64 Share weighted average – 0.37 Simple sum – 0.63 *Ghana:* Regression model – 0.37 PCA – 0.42 Share weighted average – 0.33 Simple sum – 0.38 *Nepal:* Regression model – 0.36 PCA – 0.34 Share weighted average – 0.32 Simple sum – 0.30

[6] McKenzie also explored two more complex regression methods in an attempt to allow for heteroskedasticity in error terms; these methods are not included in this review as they would make it more complex to use regression coefficients as weights for a wealth index, and furthermore they produce slightly lower correlations between the wealth index and consumption expenditure

First author	*Dataset*	*WI-Consumption agreement*
Filmer and Scott cont.		*Nicaragua:* Regression model – 0.56 PCA – 0.51 Share weighted average – 0.48 Simple sum – 0.49 *Panama:* Regression model – 0.72 PCA – 0.71 Share weighted average – 0.65 Simple sum – 0.70 *Papua New Guinea:* Regression model – 0.36 PCA – 0.34 Share weighted average – 0.32 Simple sum – 0.33 *South Africa:* Regression model – 0.48 PCA – 0.43 Share weighted average – 0.43 Simple sum – 0.42 *Uganda:* Regression model – 0.52 PCA – 0.48 Share weighted average – 0.47 Simple sum – 0.48 *Vietnam:* Regression model – 0.54 PCA – 0.49 Share weighted average – 0.49 Simple sum – 0.48

First author	*Dataset*	*WI-Consumption agreement*
Filmer and Scott cont.		*Zambia:* Regression model – 0.42 PCA – 0.40 Share weighted average – 0.41 Simple sum – 0.42

3.4 Discussion

3.4.1 Limitations of this review

It is possible that studies have been missed. Methodological work may be more likely to remain unpublished or in the grey literature, making it more difficult to find. In addition, there are probably a significant number of studies utilising the consumption correlates approach to identifying asset indicators that do not include this information in the abstract of the paper and would not have been identified in the search process.

A further limitation is that the categorisation of the agreement between wealth indices and consumption expenditure as strong, moderate or weak was somewhat arbitrary and different cut-offs could have altered the results. The cut-off points used were rather conservative, so if one deemed more relaxed cut-offs to be acceptable, conclusions about the ability of the wealth index to proxy consumption would be more positive.

Sensitivity to the choice of measure of agreement was assessed by comparing the categorisation of the strength of agreement for the nine datasets where multiple measures were available. For five of the nine datasets, the classification of weak, moderate or strong agreement was the same for each study using that dataset. In three of the remaining four datasets, the measure chosen to be included in this review had stronger agreement than the excluded measure(s). If the choice of measure of agreement has introduced any bias into the results, it would appear that it has increased the weight of evidence in favour of the wealth index being a good proxy for consumption expenditure. Since the conclusion of the review is in the opposite direction, the effect of this potential bias is likely to be limited.

The studies included in this review were different in many ways – measurement of consumption expenditure, indicators included in the wealth index, etc. This has made formal meta-analysis of the relationship between the wealth index and consumption expenditure impossible and may also have affected the observed agreement in ways that cannot be unravelled from the available data.

3.4.2 Discussion of main findings

The main finding of this systematic review is that the ability of a wealth index to act as a proxy for consumption expenditure is variable. The majority of datasets exhibited weak agreement between the wealth index and consumption expenditure, although a non-trivial number of examples of moderate and strong agreement were identified. Since both consumption expenditure and the indicators used to construct a wealth index are subject to some degree of measurement error, some differential classification would be expected even if the true unobserved values of consumption expenditure and the wealth index were perfectly correlated. Nonetheless, the level of agreement observed is generally lower than would be expected if the wealth index were indeed a proxy for consumption expenditure.

The vast amount of literature demonstrating inequalities across a range of outcomes and in diverse settings implies that the wealth index is measuring an important determinant of health. This review, however, indicates that the underlying concept being measured by a wealth index cannot be assumed to be consumption expenditure. It is possible that a wealth index is capturing some aspects of long-term economic position, but not the same aspects that are captured by consumption expenditure. Alternatively, a wealth index may not be capturing long-term economic position at all.

Since there is variation in the level of agreement observed, there is scope for exploring, both in this review and in the subsequent analyses in this thesis, whether different approaches to wealth index construction can strengthen the agreement between it and consumption expenditure. This review provides some evidence that increasing the number of indicators included in a wealth index can result in modest gains in the strength of its agreement with consumption expenditure, as can including indicators other than consumer durables, housing characteristics and access to services. Wealth indices tended to have stronger agreement with consumption expenditure in middle-income settings compared with low-income settings, and in urban areas compared with rural areas. There is some evidence that a wealth index has somewhat higher agreement with total expenditures rather than per capita or per adult (equivalent), but the weighting method applied to the wealth index does not appear to affect agreement.

3.4.3 Implications of this review

The wealth index, despite its limited theoretical and methodological grounding, is a widely used measure of socio-economic position in epidemiological research. This review reveals that there is limited evidence to consider wealth indices - at least in the way they are commonly constructed - as accurate proxies for consumption expenditure. The theoretical concept being measured by a wealth index and the reasons for its often strong association with health remain uncertain. The interpretation of relationships between a wealth index and health is therefore difficult, and policy implications of observed inequalities are unclear. There are, however, possible approaches to wealth index construction identified in this review that may increase the ability of a wealth index to act as a proxy for consumption expenditure.

3.5 Next steps

In **Chapter 4**, I further explore the relationship between the wealth index and consumption expenditure. I analyse the relationship between the wealth index and consumption expenditure in the Malawi IHS2 dataset. I quantify the agreement between the two measures, and assess to what extent this is affected by i) the equivalence scale used to adjust consumption expenditure for household size and composition, and ii) the items included in the consumption expenditure aggregate.

4. The wealth index and consumption expenditure

This chapter builds on the systematic review to discuss and empirically evaluate the relationship between the wealth index and consumption expenditure. A wealth index is developed for the Malawi IHS2 data to match as closely as possible the wealth index used in the Malawi DHS. Subsequently, its agreement with consumption expenditure is quantified, and factors to do with consumption measurement that may affect this agreement are evaluated.

4.1 Objectives & Hypotheses

The overall chapter objective is:

- To explore the relationship between the wealth index and consumption expenditure in the Malawi IHS2 data

Specific objectives are:

1. To construct a wealth index in the Malawi IHS2 dataset that is comparable to the DHS wealth index for Malawi
2. To quantify the agreement between the wealth index and per capita consumption expenditure
3. To explore the effect on agreement between the wealth index and consumption expenditure of the equivalence scale used to adjust consumption expenditure for household size and composition
4. To quantify the agreement of the wealth index with a restricted measure of consumption expenditure, using only those consumption items more directly related to the wealth index indicators

My hypotheses are:

1. The wealth index will have low agreement with consumption expenditure

2. Agreement between the wealth index and consumption expenditure will be higher when total expenditures are used compared with when per capita expenditures are used
3. Using a restricted list of consumption items, including only those related to the indicators used to construct a wealth index will result in increased agreement between the two measures

4.2 Consumption expenditure as the gold-standard

The systematic review presented in **Chapter 3** demonstrated that there is variation in the strength of agreement between the wealth index and consumption expenditure. The vast majority of datasets included in the review had weak agreement between the wealth index and consumption expenditure, but a non-trivial number of datasets showed moderate or weak agreement.

The analyses in the present and subsequent chapters will continue to use consumption expenditure as the benchmark indictor against which to compare and evaluate different approaches to wealth index construction. I will explore some of the methodological aspects of wealth index construction identified through the systematic review as potential factors associated with stronger agreement between the wealth index and consumption expenditure. This will allow empirical testing of whether different methods of wealth index construction can improve its ability to proxy consumption expenditure.

It is important that the analyses of different wealth index construction methods employ a 'gold standard' indicator against which to judge a wealth index; it is not possible to evaluate the wealth index by its properties alone. Nor is it wise to evaluate the wealth index by its relationship with health; since my aim is to investigate the appropriateness of the wealth index as a measure of SEP, not to find the strongest predictor of health.

Consumption expenditure, despite suffering from issues of reliability, is widely considered a good measure of long-term economic position. It involves detailed measurements, careful consideration of multiple areas of consumption expenditure, adjustments for price differences across areas, and is strongly grounded in economic theory. It is considered preferable to income as a measure of economic position for low- and middle-income countries due to its greater stability and reduced sensitivity in interviews.

Households tend to save and borrow in order to 'smooth' their consumption expenditure (**Section 1.5.5**), meaning that it is determined primarily by their 'permanent income' and not strongly affected by short-term fluctuations in income. Despite the lack of clarity surrounding exactly what a wealth index is measuring, it too is aiming to measure long-term, stable, economic position. It is not unrealistic, therefore, to expect a reasonable level of agreement between the two measures, and to state that an increase in agreement between the two implies an improvement in the ability of a wealth index to measure long-term economic position.

A further justification for the use of consumption as a gold standard is that some of the analyses in subsequent chapters will assess differences in the relationship between consumption expenditure and the wealth index in different areas (urban and rural), and when different sets of indicators are used to construct the wealth index. Consumption expenditure takes careful account of price differences across urban and rural areas, whereas wealth indices are frequently applied with the same assets and same weights across diverse areas. An increase in the agreement of a wealth index with consumption expenditure in rural areas might therefore indicate that the approach to wealth index construction has gone some way to improving its ability to measure SEP in rural areas. Finally, if approaches to wealth index construction can be identified that improve the ability of a wealth index to act as a proxy for consumption expenditure, this will be beneficial for those wishing to use the wealth index as a simplified measure for economic position.

4.3 Constructing a comparable index to that used in analysis of DHS data.

Much of the advocacy for the wealth index approach has come from those working with the Demographic and Health Surveys (DHS). Many of those adopting the wealth index have used a similar set of indicators to those available within the DHS, perhaps because they were following in the footsteps of the main methodological papers detailing and justifying the approach, perhaps because of limitations in their own data availability, or perhaps for other unspecified reasons. In order to be consistent with the most commonly used methodology, and to provide a starting point for the systematic exploration of wealth index construction that follows in **Chapters 5-7**, the set of indicators used to construct the wealth index within the most recent Malawi DHS[290] will be used as a set of 'core assets'. These core assets are detailed in **Box 4.1**; their prevalence and levels of missing data are presented in **Section 2.1.4.1**.

PCA was used to construct a wealth index within the IHS2 using the core assets, using the first principal component to assign weights to the indicators. The technique of PCA will be described in detail in **Chapter 5**.

Properties of the wealth index are presented in **Table 4.1A**. The distribution of the wealth index is very right-skewed; there is a disproportionate number of households with low wealth index scores since many households own few or none of the assets. This results in 'clumping' of the wealth index, resulting in difficulty in identifying even quintiles. For instance, the second quintile contains over 27% of households, whereas the third quintile contains less than 12% of households. This clumping of scores is a feature of the wealth index distribution, but not of the consumption expenditure distribution, for which even quintiles can be generated (**Figure 2.1**).

The weights assigned to each indicator in the wealth indices for both the Malawi 2000 DHS and IHS2 are provided in **Table 4.1B**. Indicators assigned positive weights can be interpreted as being 'good' for SEP; they increase a household's wealth index score. Conversely, negative weights are associated with lower SEP, decreasing a household's wealth index score. The magnitude of weights can be compared across items within a wealth index; a higher positive weight increases the total wealth index score by more than a weight close to zero and that indicator can therefore be said to be a stronger indictor of SEP.

The weights are not directly comparable across the indices for the DHS and the IHS2. However, it is possible to make cross-datasets comparisons of the relative magnitude of an indicator compared to other indicators in the same index, and of the positive/negative signs assigned to indicators.

The weights assigned to the index are similar to those in the Malawi 2000 DHS index (**Table 4.1B**), after considering the differences in the way variables are categorised. Generally, indicators receive a weight of the same sign and similar relative magnitude in the two indices. For example, ownership of agricultural land receives a negative weight in both indices, indicating perhaps that it is indicative of wealth in some but not all areas of the country. Similarly, flush toilets receive high positive weights in both indices, VIP latrines lower positive weights, and none/other toilet facility receives negative weights. This verifies that the wealth index used in this thesis for analysis of the IHS2 dataset is similar to the index used by the DHS.

Box 4.1: The Core Assets

The following indicators were used to construct the wealth index for the 2000 Malawi DHS and will be used throughout this thesis as a starting point for wealth index construction. The categorisations shown are those within the Malawi IHS2, and may differ slightly from those in the DHS.

Drinking water source
- *Piped into dwelling*
- *Piped outside dwelling*
- *Communal standpipe*
- *Personal handpipe/well*
- *Communal handpipe/well*
- *River/spring/lake/reservoir/*
- *Other*

Toilet facility
- *Flush toilet*
- *VIP latrine*
- *Traditional latrine with roof*
- *Traditional latrine no roof*
- *None or other*

Cooking fuel
- *Collected firewood*
- *Purchased firewood*
- *Paraffin/gas/charcoal*
- *Electricity*
- *Crop residue/sawdust/other*

Material of dwelling floor
- *Sand*
- *Smoothed mud/other*
- *Smoothed cement/wood/tiles*

Electricity in the household

Television/VCR

Radio

Bicycle

Motorbike/scooter

Car

Domestic servant within the household

Household owns agricultural land

Table 4.1: Properties of the wealth index

A: Summary statistics of the wealth index from the Malawi IHS2

Mean (SD)	-0.029135 (0.9485)
Minimum	-0.6436075
Maximum	5.943318
Percentiles	
5th	-0.6436075
10th	-0.6021441
25th	-0.5377453
50th	-0.488326
75th	0.119463
90th	1.154372
95th	2.01171
% Households per quintile	
Q1	20.7
Q2	27.6
Q3	11.9
Q4	19.7
Q5	20.1

B: Weights assigned to indicators using the first principal component, from the Malawi IHS2 and the Malawi 2000 DHS

Indicator	*Weight in DHS Index*	*Weight in IHS2 Index*
Drinking water source		
Piped into dwelling	0.1378	0.2762
Piped outside dwelling	0.06867	0.1630
Public faucet	0.01388	
Communal standpipe		0.1250
Personal handpipe/well		0.0154
Unprotected well	-0.03761	
Protected well	-0.01261	
Communal handpipe/well		-0.2269
Borehole	-0.04090	
River/spring/lake/reservoir/other		-0.0433
River/canal/surface water	-0.02524	
Spring	-0.00762	
Rain	-0.00086	
Drinking water from tanker truck	0.00005	
Bottled water	0.00085	
Toilet facility		
Flush toilet	0.1409	0.2760
Shared flush toilet	0.03100	
VIP latrine	0.01590	0.0893
Shared VIP latrine	0.01561	
Traditional latrine with roof		0.0014
Traditional latrine no roof		-0.0611
Pit latrine	-0.02385	

Indicator	*Weight in DHS Index*	*Weight in IHS2 Index*
Shared pit latrine	-0.00061	
None or other	-0.04178	-0.0923
Cooking fuel		
Collected firewood		-0.3047
Purchased firewood		0.1251
Wood	-0.1431	
Paraffin/gas/charcoal		0.2194
Kerosene	0.02580	
Charcoal	0.07148	
Electricity	0.1361	0.2452
Crop residue/sawdust/other	0.00237	0.0042
Material of dwelling floor		
Sand		-0.0078
Smoothed mud/other		-0.3116
Smoothed cement/wood/tiles		0.3313
Dirt/sand dung	-0.1429	
Wood planks	0.00768	
Broken brick	0.00220	
Tiles	0.01412	
Cement	0.1422	
Parquet or polished wood	0.01117	
Vinyl/asphalt strips	0.00325	
Electricity in the household	0.1593	0.3426
Television/VCR	0.1273	0.2835
Radio	0.06274	0.0194
Bicycle	0.00528	0.0026
Motorbike/scooter	0.03549	0.0432
Car	0.08596	0.1887
Domestic servant within the household	0.05008	0.1425
Household owns agricultural land	-0.04972	-0.2279

4.4 Agreement of the wealth index with consumption expenditure

Consistent with the majority of the datasets included in the systematic review in **Chapter 3**, the wealth index and per capita consumption expenditure demonstrate very low agreement in the Malawi IHS2 dataset. Less than 30% of households are in the same quintile, and more than 30% of households move by two or more quintiles **(Table 4.2)**.

The strongest agreement is seen for those households in the top quintile of per capita consumption expenditure, where almost half are also in the top quintile of the wealth index. Despite this relatively high degree of agreement of classification, almost ten percent of the households in the top expenditure quintile are in the bottom wealth index quintile. Agreement is very poor for households in the bottom quintile of consumption expenditure; each of the bottom four quintiles of the wealth index contains at least 15% of these households. Lower agreement in the lower quintiles may reflect the clumping of wealth index scores at lower values.

The Kappa statistic is a measure of agreement between categorical variables. In contrast to a simple percentage of agreement of classification, the kappa statistic takes into account the agreement expected by chance. If there is complete agreement, the Kappa statistic equals one; if there is no agreement beyond that expected by chance, the Kappa statistic is less than one. There are no universally accepted values of Kappa that indicate good agreement, but the observed value of 0.11 would widely be considered to demonstrate poor agreement **(Table 4.2)**.

Correlations between the wealth index and per capita consumption expenditure, and between the logged values of each measure, are approximately 0.5 **(Table 4.2)**.

Table 4.2: Agreement of classification into quintiles by the wealth index and per capita consumption expenditure

A: Summary

Number of quintiles moved	Percentage of households
0	28.9
1	33.5
2	20.4
3	13.6
4	3.6
Kappa (SE)	*0.11 (0.005)*
Correlation	*0.54*
Correlation of logged measures	*0.46*

B: Full transition matrix

		Quintile of per capita consumption expenditure				
		1	2	3	4	5
Quintile of wealth index	1	634 (28.22%)	543 (24.13%)	504 (22.39%)	427 (19.00%)	218 (9.70%)
	2	739 (32.89%)	699 (31.07%)	703 (31.23%)	550 (24.48%)	414 (18.42%)
	3	343 (15.26%)	330 (14.67%)	275 (12.22%)	258 (11.48%)	133 (5.92%)
	4	415 (18.47%)	453 (20.13%)	444 (19.72%)	490 (21.81%)	414 (18.42%)
	5	116 (5.16%)	225 (10.00%)	325 (14.44%)	522 (23.23%)	1,069 (47.55%)

4.5 The effect of the equivalence scale for consumption expenditure

4.5.1 Background

Both consumption expenditure and wealth indices are measured using household-level data. Equivalence scales are generally applied to consumption expenditure data in order to allow for household size and composition. The most frequently used equivalence scales are per capita (i.e. divided by the total number of household members) or per adult equivalent (the number of children is multiplied by a pre-defined value of less than one because they are expected to consume less than an adult; this total is added to the number of adults. The value of less than one used varies between researchers and studies, depending on the setting and the researcher's views of the relative 'cost' of children compared with adults; in some cases a simple per adult scale is used where children are not included at all in the number of household members). Wealth indices, however, are not generally adjusted for household size or composition. There is some evidence that adjusting a wealth index for household size results in implausible relationships with health outcomes.[56] It has also been argued that whilst consumption needs and patterns will obviously be strongly affected by household size and composition, the benefits of most items included in a wealth index are at the household level.[56] It has, however, been demonstrated that wealth indices and per capita expenditures produce very different patterns in household size; in 11 low-income countries, the poor-rich difference in average household size was consistently greater when using per capita expenditures compared with a wealth index.[286] Thus the poorer quintiles of the wealth index contained, on average, larger households than the poorer quintiles of per capita consumption expenditure. This indicates that households with a greater number of members, a factor widely considered to be strongly linked with poverty, would not always end up in the lower quintiles of a wealth index.

In considering the appropriateness of a wealth index as a proxy for consumption expenditure, it has been suggested that the choice of equivalence scale may have an impact on the observed relationship. Sahn and Stifel suggested that the correlation of a wealth index would be highest when total household expenditures were considered, intermediate when a per adult equivalence scale is used, and lowest when per capita consumption expenditure is used.[67]

4.5.2 Methods

In order to explore the effect of choice of consumption expenditure equivalence scale on the appropriateness of a wealth index as a proxy for consumption expenditure, I examine the pattern of household size across quintiles of i) total per capita consumption expenditure, ii) per adult consumption expenditure (using number of adults, excluding children from the calculations), iii) per capita consumption expenditure, and iv) the wealth index using the core set of assets. The agreement of the wealth index with each measure of consumption expenditure will also be assessed, using cross-tabulations of quintiles and Kappa statistics. Adults were defined as over 16 years of age.

4.5.3 Results

The patterns of household size across quintiles of the different SEP measures differ markedly (**Table 4.3**). Total expenditure, as might be expected, has increasing household size across the increasing quintiles. Per adult expenditures has roughly the same average household size across the quintiles. Per capita expenditures, on the other hand, has decreasing household size with increasing quintiles. This pattern could be considered to be the most appropriate as a measure of poverty, since poorer households tend to have more members and in particular more children. The wealth index has a similar pattern of household size to per adult expenditures, i.e. the mean household size varies little across the quintiles of the wealth index. This may imply that agreement between the wealth index and consumption expenditure should be highest when a per adult adjustment is made to expenditures. This suggestion, however, does not hold true when the data are examined. Agreement between the wealth index and consumption expenditure is equally modest for total, per adult and per capita expenditures (**Table 4.4**). Differences between agreement when using the alternative equivalence scales are minimal for the overall population, and for peri-urban areas. In urban areas, agreement is lowest for total expenditures, intermediate for per adult expenditures and highest for per capita expenditures. Differences in agreement in rural areas are fairly small but agreement is highest when using total expenditures.

Table 4.3: Household size across quintiles of different measures of consumption expenditure and the core wealth index

	Mean (SD) number of household members					
	Overall	Q1 (low)	Q2	Q3	Q4	Q5 (High)
Total consumption expenditure	*4.55 (2.34)*	3.31 (1.84)	4.33 (1.96)	4.77 (2.10)	5.29 (2.36)	5.97 (2.66)
Per adult consumption expenditure	*4.55 (2.34)*	4.80 (2.52)	4.56 (2.32)	4.48 (2.22)	4.48 (2.31)	4.51 (2.30)
Per capita consumption expenditure	*4.55 (2.34)*	6.16 (2.27)	5.24 (2.06)	4.71 (2.08)	4.19 (2.08)	3.32 (2.18)
Wealth index	*4.55 (2.34)*	4.40 (2.25)	4.63 (2.24)	4.35 (2.27)	4.67 (2.37)	4.61 (2.54)

Table 4.4: Agreement of the core wealth index with different measures of consumption expenditure

	% Households moving between quintiles of wealth index and per capita consumption expenditure					
Index	**Same quintile**	**Move 1 quintiles**	**Move 2 quintiles**	**Move 3 quintiles**	**Move 4 quintiles**	***Kappa (SE)***
Total consumption expenditure						
Whole population (n=11243)	28.8	34.7	21.7	12.1	2.7	*0.10 (0.005)*
Urban areas (n=1434)	38.2	26.1	18.5	11.0	6.2	*0.10 (0.01)*
Peri-urban areas (n=739)	35.1	30.7	16.7	14.2	3.3	*0.16 (0.02)*
Rural areas (n=9072)	26.8	36.4	22.7	12.1	2.0	*0.059 (0.005)*
Per adult consumption expenditure						
Whole population (n=11243)	27.3	35.7	21.1	12.8	3.0	*0.090 (0.005)*
Urban areas (n=1434)	44.2	26.6	17.1	8.7	3.3	*0.14 (0.01)*
Peri-urban areas (n=739)	38.1	30.5	16.9	11.7	2.8	*0.17 (0.02)*
Rural areas (n=9070)	23.8	37.6	22.0	13.6	3.0	*0.034 (0.05)*
Per capita consumption expenditure						
Whole population (n=11243)	28.9	34.5	21.5	11.6	2.9	*0.11 (0.005)*
Urban areas (n=1434)	54.7	24.0	12.7	6.6	2.1	*0.16 (0.01)*
Peri-urban areas (n=739)	37.5	35.4	14.7	10.7	1.8	*0.13 (0.02)*
Rural areas (n=9070)	24.1	34.9	22.1	15.0	4.0	*0.052 (0.005)*

4.5.4 Conclusion

The equivalence scale used to adjust consumption expenditure for household size and composition makes little difference to the agreement with the wealth index. Although the pattern of household sizes across quintiles of the wealth index is more similar to the pattern for per adult expenditures, per capita consumption will continue to be used for this thesis. Per capita is the more commonly used equivalence scale in the existing methodological research on wealth indices. Furthermore, the pattern of household size across quintiles of per capita expenditures better fits with the generally accepted notion that poorer households tend to be larger.

4.6 Using a restricted measure of consumption expenditure

4.6.1 Background

The full consumption expenditure aggregate includes 12 categories of expenditures: food/beverages, alcohol/tobacco, clothing/footwear, housing/utilities, furnishing, health, transport, communications, recreation, education, vendors/cafes, and miscellaneous goods and services. The wealth index, however, contains items relating to only a few of these categories. It would therefore be interesting to calculate the agreement of the wealth index with a restricted measure of consumption expenditure, using only those categories relevant to items included in the wealth index. This may provide insight into what the wealth index is measuring.

4.6.2 Methods

The wealth index using the core assets was compared with an aggregate of per capita consumption expenditure from the following categories, which are those relevant to the indicators included in the wealth index:

1. **Housing/utilities** – actual rents for housing, estimated rents for housing, regular maintenance and repair of dwelling, and electricity, gas and other fuels
2. **Furnishing** – decorations, carpets, household textiles, appliances, dishes, tools/equipment for the home, routine home maintenance
3. **Transport** – vehicles, operation of vehicles, transport

The aggregate of these three categories of per capita consumption expenditure (which will be referred to as the restricted consumption aggregate) was compared with the wealth index in terms of agreement of classification into quintiles.

4.6.3 Results

The agreement between the wealth index and the restricted consumption aggregate is no better than the agreement with the full consumption aggregate (**Table 4.5**). In both cases, only approximately 28% of households are in the same quintile by the two measures, and a Kappa statistic of approximately 0.1 is observed. The extent of gross misclassification (i.e. disagreement by more than one quintile) is also similar for both the full and restricted consumption aggregates.

Table 4.5: Agreement of classification into quintiles between the wealth index, the full consumption aggregate and the restricted consumption aggregate

	Percentage of households in same quintile as the wealth index	
	Full consumption aggregate	*Restricted consumption aggregate*
Same quintile	28.9	27.7
Moved 1 quintile	34.5	33.6
Moved 2 quintiles	21.5	21.5
Moved 3 quintiles	11.6	13.6
Moved 4 quintiles	2.9	3.6
Kappa (SE)	0.11 (0.005)	0.10 (0.002)

4.6.4 Conclusion

If the wealth index had higher levels of agreement with the restricted consumption aggregate than with the full consumption aggregate, this would imply that the wealth index was able to act effectively as a simplified proxy for consumption expenditure in the sub-categories included in the restricted aggregate. This would indicate that inclusion of additional variables in the wealth index that represent the other sub-categories of consumption expenditure could potentially improve agreement with overall consumption expenditure. There is, however, no evidence to support this notion. The agreement was equally modest between the wealth index and the full consumption aggregate and between the wealth index and the restricted consumption aggregate, indicating that it is not a lack of indicators related to food and other sub-categories of expenditures that is causing the wealth index to have low agreement with consumption expenditure.

4.7 Chapter key messages

1. Agreement between the wealth index and consumption expenditure is low in the Malawi IHS2 dataset
2. Agreement is not altered substantially by the equivalence scale used for consumption expenditure
3. Agreement is not improved by using the restricted subset of consumption expenditure items most relevant to the indicators in the wealth index

4.8 Next steps

This chapter has explored the relationship between the wealth index and consumption expenditure, which forms the basis of much of the analysis to be conducted in the next part of this thesis. Different approaches to wealth index construction will be judged, at least in part, on whether or not they strengthen the agreement between the wealth index and consumption expenditure.

The next section of this thesis moves on to address my second research question: Are the methods used to construct wealth indices with DHS data the most appropriate? **Chapter 5** focuses on weighting the indicators in a wealth index, discussing and analysing the issues surrounding the use of principal components analysis and evaluating potential alternative weighting methods.

Part III: Are the methods used to construct wealth indices from DHS data the most appropriate?

5. Using Principal Components Analysis to construct a wealth index

This section, Part III, of the thesis addresses the second of my main research questions: are the methods used to construct wealth indices from DHS data the most appropriate? It explores three of the key issues in constructing a wealth index: i) the way the indicators are weighted to form the wealth index, ii) issues surrounding area and the wealth index, and iii) the indicators used to construct the wealth index.

This chapter focuses on the issue of weighting indicators in a wealth index. The use of Principal Components Analysis (PCA) to weight the indicators in a wealth index is introduced, discussed, and evaluated in comparison with alternative weighting methods.

5.1 Objectives & Hypotheses

The overall chapter objective is:

- To explore issues in the use of Principal Components Analysis for weighting the indicators in a wealth index

The three main objectives to be covered in this chapter are:

1. To explore the consequences of only using the first principal component in PCA
2. To explore the use of discrete data in PCA
3. To explore alternatives to PCA for generating a wealth index

Specific objectives will be detailed in each section of the chapter.

My main hypotheses are:

1. Using higher order principal components in addition to the first principal component will be unnecessary

2. Statistically inappropriate ways of including discrete data in PCA for a wealth index will affect the classification of households across the wealth index distribution
3. Alternative methods of wealth index construction are likely to have a relatively small impact on the final wealth index, but may offer advantages over PCA in terms of statistical appropriateness or ease of interpretation

5.2 Principal Components Analysis

When constructing a wealth index from a set of variables, a decision must be made about the weights to assign to each indicator. Principal Components Analysis (PCA) was recommended as a method for determining weights for components of a wealth index by Filmer and Pritchett following a meeting to discuss potential economic indicators within the DHS.[29, 56] Following Filmer and Pritchett's paper, the use of PCA for wealth index construction was rapidly adopted by those performing analyses of socio-economic inequalities within the DHS.[290-292] The technique is now widely used by those using the wealth index approach, as was demonstrated in **Section 1.8**. Guidelines for the use of PCA for wealth index construction were recently published by Vyas & Kumaranayake.[62]

PCA is a 'data reduction' procedure that was developed by Karl Pearson and is widely used in psychometrics, for example for combining the results of several different tests. In essence, it involves replacing a set of correlated variables with a set of uncorrelated 'principal components' which represent unobserved characteristics of the population. The principal components are linear combinations of the original variables; the weights are derived from the correlation matrix of the data or the covariance matrix if the data have been standardised prior to PCA. Standardisation is desirable if the indicators have markedly different scales, since in this situation PCA will pick the variable with the highest variance as the source of most variation.[293]

The first principal component explains the largest proportion of the total variance, and each subsequent higher order component explains a lower proportion. If the first few principal components explain a substantial proportion of the total variance, they can be used to represent the original items, thus reducing the number of variables required in models.[294]

For constructing a wealth index, the first principal component is taken to represent the household's SEP.[295] Assets that are more unequally distributed across the sample will have a higher weight in the first principal component.[62] The weights for each indicator from this first principal component are used to generate a household score, with higher weights indicating higher SEP and vice versa. The relative rank of households using the score generated from the first principal component is then used as a measure of relative SEP, enabling estimation of a single estimate of the effect of wealth.[296] The most common way of using wealth index scores is to divide the population into quintiles.

Factor analysis (FA) is an alternative technique that could have been used instead of PCA. Statistically, the difference between the two methods is that PCA analyses all variance in the indicators, whereas FA analyses only the shared variance. Conceptually, there is also a difference between the approaches. In PCA, the indicators are viewed as giving rise to the underlying latent concept; in FA this is reversed, with the underlying concept giving rise to the indicators. Conceptually, therefore, FA could be considered more appropriate than PCA. SEP is likely to affect asset ownership, rather than the other way around. Filmer and Pritchett do not discuss the reasons why PCA was selected in preference over FA, although they do note that wealth indices generated using the two methods had very high correlation indeed (Spearman's rank correlation coefficient 0.988).[29] Given the high degree of correlation between the resultant indices and the fact that PCA is far more widely used in the literature than PCA, this thesis will continue to consider PCA rather than FA.

5.3 Using the first principal component

In the general use of PCA, several principal components are often used such that together, they explain a substantial proportion of the overall total variance.[294] The use of a single principal component as the measure of SEP could be questioned, since the first principal component from PCA of a set of assets frequently explains a low proportion of the total variation in those assets (often less than 20%).[29, 62, 297] It could be the case that the theoretical 'wealth' construct is multidimensional, with the first few principal components each capturing a specific aspect of wealth. Using only the first principal component would in this case not capture the entire wealth effect.

The aim of using PCA to generate a wealth index is to define a single indicator of SEP, and using multiple principal components would not be compatible with this. It would not be possible to generate a single estimate of the magnitude of socio-economic inequalities if multiple principal components were used.

If the first principal component explains a small proportion of the total variance, each subsequent higher order component will explain a smaller proportion still, so using two or three principal components may not drastically improve the proportion of the total variance explained, for instance in the Malawi IHS2 data using the core assets, the first principal component explains 18.9%, the second 9.4% and the third 6.8%, such that using three principal components would still only explain 35.1% of the total variance.

It is also generally not straightforward to identify which aspects of SEP higher order principal components might represent, since there is not usually a clear pattern of which assets are assigned positive/negative or higher/lower weights. **Table 5.1** shows the weights assigned to the core assets in the Malawi IHS2 in the first three principal components. It is certainly not easy to identify an aspect of SEP for which the weights in the second and third principal components would be appropriate; the combinations of indicators assigned strongly positive or strongly negative weights in any of the higher order principal components do not easily relate to any notion of SEP. For instance, in the second principal component having no toilet facility gains a positive weight, and in the third principal component all toilet facilities apart from traditional latrines with a roof gain negative weights.

Table 5.1: Weights assigned to indicators in the first three principal components

Indicator	*Principal Component 1*	*Principal Component 2*	*Principal Component 3*
Drinking water source			
Piped into dwelling	0.2762	0.3597	-0.0027
Piped outside dwelling	0.1630	-0.1140	-0.0317
Communal standpipe	0.1250	-0.3261	-0.1948
Personal handpipe/well	0.0154	-0.0462	0.0234
Communal handpipe/well	-0.2269	0.1895	0.2970
River/spring/lake/reservoir/other	-0.0433	0.0294	-0.2376
Toilet facility			
Flush toilet	0.2760	0.3232	-0.0139
VIP latrine	0.0893	-0.1216	-0.0747
Traditional latrine with roof	0.0014	-0.2279	0.5463
Traditional latrine no roof	-0.0611	0.0594	-0.3189
None or other	-0.0923	0.1412	-0.3435
Cooking fuel			
Collected firewood	-0.3047	0.2444	0.0722
Purchased firewood	0.1251	-0.2283	0.0070
Paraffin/gas/charcoal	0.2194	-0.2454	-0.1135
Electricity	0.2452	0.3285	0.0161
Crop residue/sawdust/other	0.0042	-0.0260	-0.0652
Material of dwelling floor			
Sand	-0.0078	-0.0079	-0.0339
Smoothed mud/other	-0.3116	0.1599	-0.0803
Smoothed cement/wood/tiles	0.3313	-0.1650	0.0990
Electricity in the household	0.3426	0.1301	-0.0031
Television/VCR	0.2835	0.1990	0.0732
Radio	0.0194	-0.0887	0.2844
Bicycle	0.0026	-0.0123	0.3398
Motorbike/scooter	0.0432	0.0304	0.1034
Car	0.1887	0.2472	0.0772
Domestic servant within the household	0.1425	0.1460	0.1176
Household owns agricultural land	-0.2279	0.1908	0.1406

Further to the reasons relating to the desire for a single measure of SEP and the difficulty in interpreting higher order principal components, there is some evidence that utilising higher order principal components is unnecessary. McKenzie demonstrated that the standard deviation of higher order components was not associated with consumption expenditure, whereas that of the first principal component was.[297] Filmer and Pritchett noted that including higher order components in multivariable regressions on school enrolment resulted in little effect on point estimates.[29]

5.4 *The use of PCA with discrete data*

5.4.1 Background

PCA is designed for use with continuous, normally-distributed data. Its application to the predominantly discrete data in a wealth index is therefore inappropriate. This issue has largely been ignored by those advocating and using PCA for wealth index construction.

The most common way of dealing with categorical variables in PCA for wealth index construction is to use dummy variables. This is the approach used by Filmer & Pritchett[29], the report on inequalities in 56 DHS countries[58], the recent guidance paper on the use of PCA for wealth index construction[62] and by most others using PCA to make a wealth index. The use of dummy variables for each category of categorical variables is problematic because the linear dependence between the dummy variables may lead to incorrect estimates of the wealth index. Using this approach, there is variation in the data arising both from the underlying concept of wealth and from the linear dependence between dummy variables of categorical variables; this could 'confuse' the PCA method and alter the weights assigned to the indicators. Using dummy variables to model categorical variables is warranted when the categorical variable is an explanatory one, but in PCA the indicator variables should be treated as dependent variables (i.e. outcomes of SEP rather than determinants of it) and therefore need to be modelled appropriately.[293] PCA is based on the Pearson correlation coefficient, which has no meaning for binary dummy variables. It is probably reasonable, however, to use PCA as an approximate method with ordinal variables. In this case, the score of the ordinal variable is treated as a metrical score, for which the correlation coefficient has some meaning. This is most reasonable for an ordinal variable with a large number of categories.[294]

Kolenikov & Angeles compared four methods of dealing with ordered categorical variables in PCA: i) using dummy variables, ii) treating ordinal variables as continuous terms, iii) using PCA with polychoric correlations, and iv) using groups means.[293] In a large simulation study, the indices constructed with each method of dealing with categorical variables were compared with the 'true' underlying score from which the categorical variables were generated. The use of dummy variables was shown to be inferior to all other methods in all measures of performance: proportion of variance explained by the first principal component, correlation with the 'true' underlying score, and misclassification compared with the 'true' underlying score. Using dummy variables also lead to an increased concentration of the weights on a few specific indicators. Using ordinal variables as continuous variables, or using PCA with polychoric correlations performed similarly, and both were slightly better than using group means.[293]

PCA with polychoric correlations is PCA performed on the polychoric correlation matrix of the data. The polychoric correlation between two ordinal variables is generated by assuming that each of them has arisen through the categorisation of an underlying normally-distributed variable, and estimating the maximum likelihood of the correlation between them.[294] It is more computationally intensive than standard PCA, but a Stata program written by Kolenikov is easily available.

Despite being inappropriate, the use of dummy variables persists and the use of ordinal variables in standard PCA or the application of PCA with polychoric correlations is rare, perhaps due to the practices suggested by Filmer & Pritchett becoming 'standard', or perhaps due to reluctance to assign an order to the categorical variables used in a wealth index. It could be argued that the categorical indicators used for wealth indices are not ordinal. It is not necessarily straightforward, for instance, to rank different sources of drinking water, and to assume that they are equally spaced from each other in terms of their relationship with SEP.

In addition to the problems caused by spurious correlations introduced by using dummy variables for categorical variables, dummy variables are often used incorrectly in PCA for wealth index generation. In the general use of dummies for categorical variables in any statistical model, k-1 dummy variables are used for a variable with k categories. A baseline category is excluded from models. This is because if a variable has categories x and y, knowing x means that y is also known; variance(x) = variance(y) and correlation(x,y)=-1. In wealth index construction, however, dummy variables are often used for all categories; no baseline category is omitted. This is the approach taken by the main proponents of the method, the authors of the guideline paper on its use, and the large report using the wealth index to quantify inequalities in 56 DHS datasets.[29, 58, 62] I was only able to identify one study that clearly states that one dummy variable for each categorical variable was excluded from PCA; in this study, the category believed to be associated with the lowest SEP is excluded, in order to be consistent with the treatment of binary indicators.[273]

The correlation matrix created by Stata when carrying out PCA needs to be singular in order to be inverted to get the eigenvalues and eigenvectors. When dummy variables for all categories of categorical variables are included in the analysis, there is collinearity between these dummy variables. This alters the values of the eigenvectors (weights used in the wealth index) for all principal components.[293] It is thus difficult to justify using the eigenvectors from PCA using dummy variables for all categories of categorical variables, since they depend on a collinear variable.

There are therefore two important issues relating to the use of categorical variables in PCA: i) the use of dummy variables for all categories or categorical variables, and ii) the use of dummy variables in preference over other method of dealing with discrete data. Kolenikov & Angeles demonstrated using simulated data that both of these issues are problematic, but the extent to which they affect the final wealth index is unknown.

5.4.2 Objectives

The objectives of this work are as follows:

1. To investigate the implications of including in PCA dummy variables for all categories of categorical variables.
2. To investigate the implications of using PCA with dummy variables compared with using ordinal variables or using PCA with polychoric correlations

5.4.3 Methods

5.4.3.1 Including dummy variables for all categories

In order to investigate the effects of either including or excluding the dummy variable for the lowest category of categorical variables, wealth indices were constructed using the core set of assets and i) including a dummy variable for each category of categorical variables, ii) dropping the dummy variable for the lowest SEP indicator of each categorical variable, and iii) dropping the dummy variable for the lowest frequency dummy variable of each categorical variable.

Agreement between the resultant wealth indices was assessed by scatter diagrams and cross-tabulations of classification into quintiles. Agreement of each wealth index with consumption expenditure is also calculated. Quintiles were used since this is the most common way of using a wealth index, and also because skewness and kurtosis is non-trivial for both the wealth index and consumption expenditure (wealth index: skewness = 2.78, kurtosis = 12.06; consumption expenditure: skewness = 7.82, kurtosis = 120.6 in the Malawi IHS2 data). The effect on the distribution of the wealth indices is assessed using histograms. For comparative purposes, these analyses are presented for both the Malawi IHS2 dataset and the Brazil DHS data.

The indicators used to construct the wealth indices for Malawi and Brazil are somewhat different. In Malawi, the core set of assets includes four categorical variables – toilet facility, water source, floor material, and cooking fuel. In Brazil, there are five categorical variables – water source, toilet facility, floor material, wall material, and roof material. Lowest SEP categories are based on subjective decisions. The details of excluded categories are shown in **Table 5.2.** The distribution of households between the categories of categorical variables for the Brazil dataset is shown in **Appendix A.**

Table 5.2: Details of categorical variables used in the wealth indices; categories excluded from PCA

Variable	Malawi IHS2		Brazil DHS	
	Lowest SEP category	**Lowest frequency category**	**Lowest SEP category**	**Lowest frequency category**
Cooking fuel	crop residue/ saw-dust/other	crop residue/ saw-dust/other		
Water source	river/lake/ other	Piped into dwelling	Well/spring outside	Other water source
Toilet facility	None/other	VIP latrine	No toilet	Other toilet facility
Floor material	Mud	Sand	Earth/sand	Vinyl
Wall material			Unpolished mud	Other wall material
Roof material			Clay tiles	Other roof material

5.4.3.2 Alternative methods for dealing with categorical data

In order to compare the consequences of using dummy variables with other methods of dealing with categorical variables, three wealth indices were constructed: i) using dummy variables for all categories, ii) assigning an ordinal structure to categorical variables and treating them as continuous in standard PCA, and iii) assigning an ordinal structure to categorical variables and using PCA with polychoric correlations.

Assigning an ordinal structure to the categorical variables is not necessarily straightforward. Without a detailed knowledge of the conditions within a setting (and note this could vary between regions of a country), assigning an order to categories will be based on subjective judgements. In order to make this process as objective as possible, I ordered the categories according to the mean consumption expenditure level for each category. Note that this resulted in some differences between the ordering imposed by PCA using dummy variables; amongst water sources PCA using dummy variables ranked communal handpump/well as lower than river/spring/lake/reservoir, and amongst floor materials PCA using dummy variables ranked smoothed mud floors as lower than sand floors, but these patterns were reversed in the ordering implied by mean consumption expenditure (**Table 5.3**). Since creation of the ordinal structure used consumption expenditure data, these analyses are restricted to the Malawi IHS2 dataset.

Table 5.3: Categorical variables; orders implied by PCA using dummy variables and mean per capita expenditure

Variable	Freq.	Percent	Weight from PCA when using all dummy variables	Mean per capita expenditure
Household water source				
Piped into dwelling	244	2.16	0.2762	108842.6
Piped outside dwelling	377	3.34	0.1630	45187.37
Communal standpipe	1,835	16.28	0.1250	27812.47
Personal handpump or well	323	2.86	0.0154	27748.53
River, spring, lake, reservoir, other	954	8.46	-0.0433	18430.64
Communal handpump or well	7,541	66.89	-0.2269	20851.05
Household toilet facility				
Flush toilet	318	2.82	0.2760	92123.27
VIP latrine	233	2.07	0.0893	34971.95
Traditional latrine with roof	6,516	57.81	0.0014	23942.4
Latrine without roof	2,356	20.90	-0.0611	21061.11
None or other	1,848	16.40	-0.0923	19167.55
Household cooking fuel				
Electricity	179	1.59	0.2452	121766.4
Paraffin, gas, or charcoal	775	6.87	0.2194	47104.95
Purchased firewood	1,700	15.08	0.1251	29447.18
Crop residue, saw dust, or other	129	1.14	0.0042	21885.12
Collected firewood	8,490	75.31	-0.3047	19712.7
Dwelling floor material				
Smooth cement, wood, tiles	2,270	20.13	0.3313	42744.18
Sand	345	3.06	-0.0078	19623.17
Smoothed mud, other	8,663	76.81	-0.3116	20189.2

The resultant wealth indices were compared with each other in terms of i) distribution, ii) weights assigned to the indicators, iii) agreement with consumption expenditure, agreement of classification into quintiles between pairs of indices, and scatter diagrams between pairs of indices.

5.4.4 Results

5.4.4.1 Including dummy variables for all categories

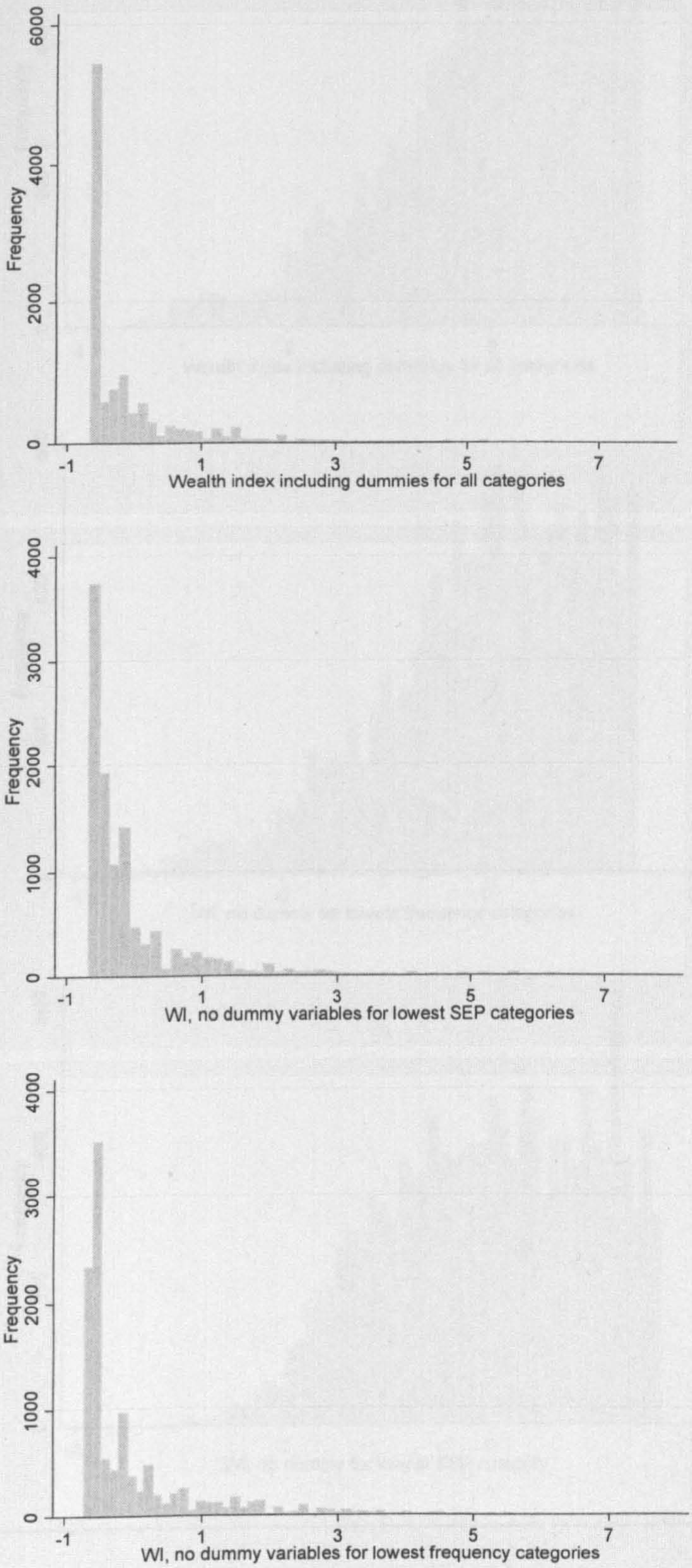
Distribution of the indices

The distribution of the wealth indices in Malawi and Brazil differ markedly; in Malawi the distribution is severely right-skewed, whereas in Brazil there is negative skew. This reflects the fact that a broadly similar set of indicators have been used to construct the two indices, but many households in Malawi have access to few or none of the items whereas many households in Brazil have access to many or all items.

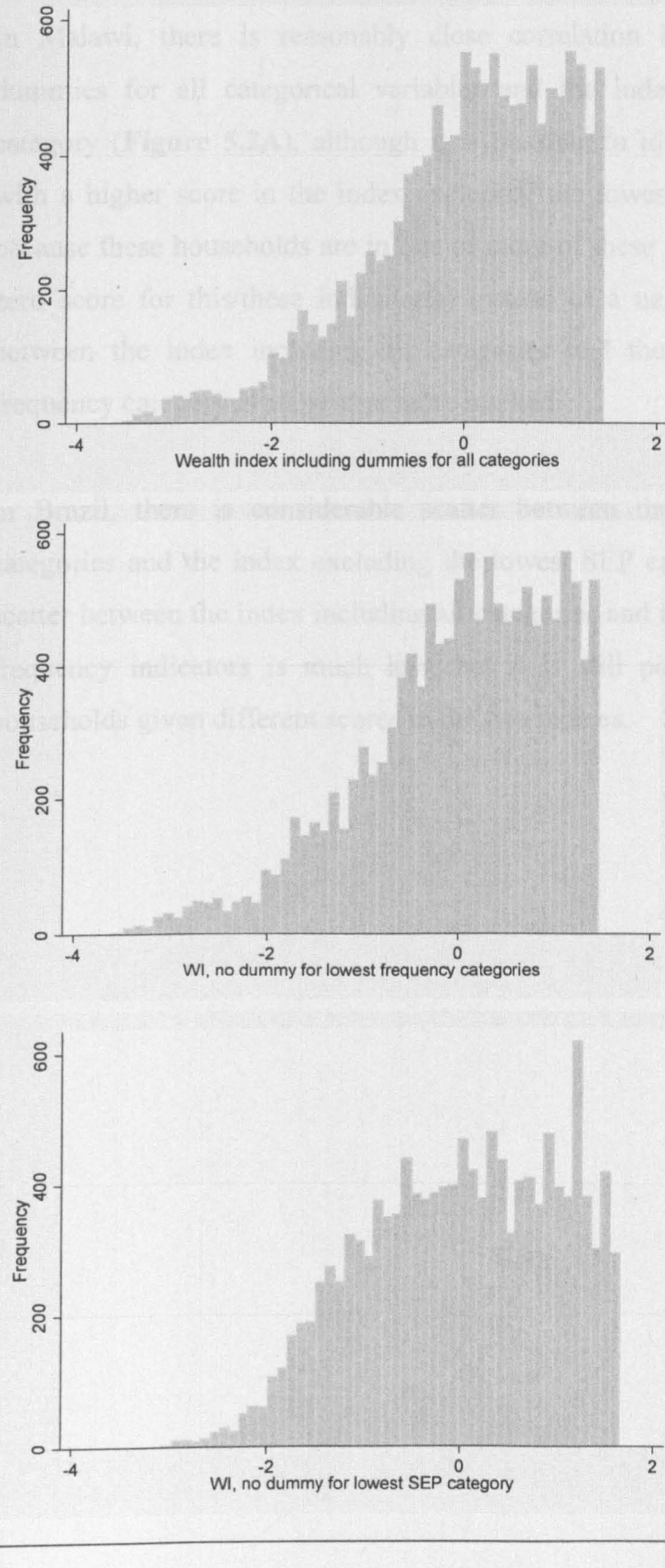
In Malawi, including or excluding the dummy variables for the lowest SEP or lowest frequency categories of categorical variables has little effect on the distribution of the wealth index (**Figure 5.1A**). In Brazil, the wealth index including dummy variables for all categories of categorical variables is very similar to the wealth index excluding the lowest frequency categories (**Figure 5.1B**). The wealth index scores excluding the lowest SEP category appear to be slightly more concentrated towards the middle of the distribution.

Figure 5.1: Distribution of wealth indices including all categories of categorical variables, or excluding one dummy variable for each categorical variable

A: Malawi



B: Brazil


Frequency
0
200
400
600
-4
-2
0
2
Wealth index including dummies for all categories
Frequency
0
200
400
600
-4
-2
0
2
WI, no dummy for lowest frequency categories
Frequency
0
200
400
600
-4
-2
0
2
WI, no dummy for lowest SEP category

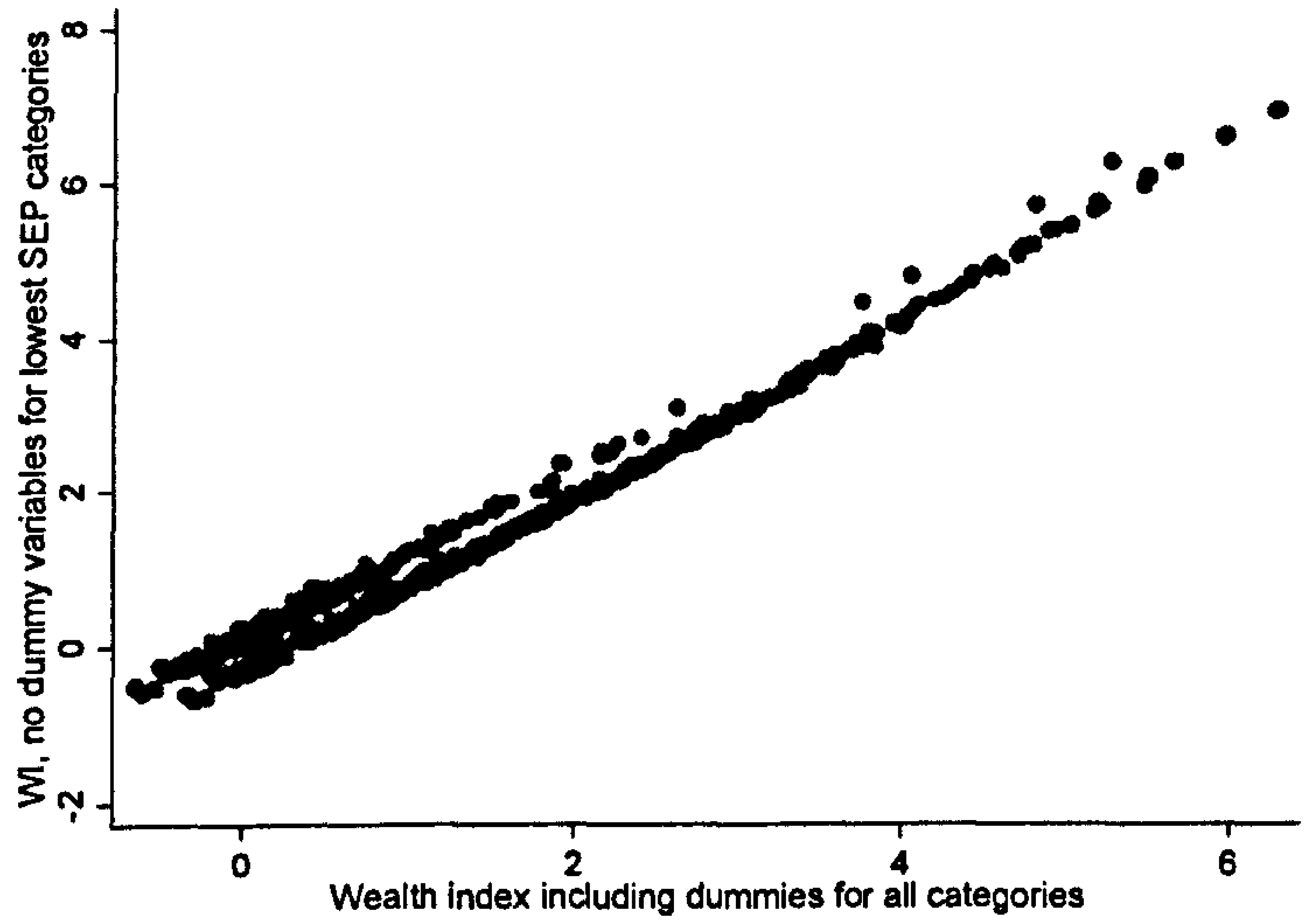
Agreement of the wealth indices

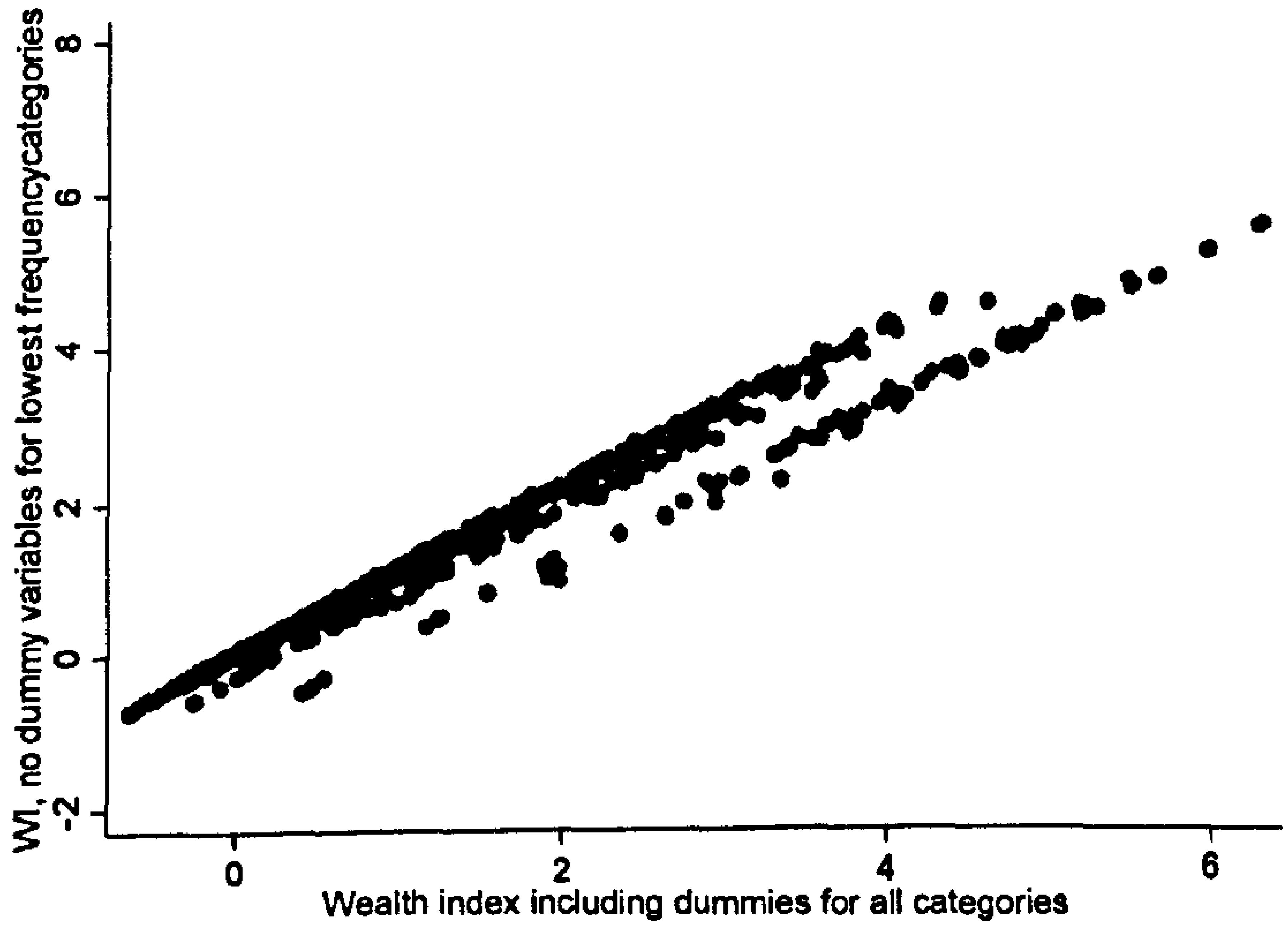
In Malawi, there is reasonably close correlation between the index including dummies for all categorical variables and the index excluding the lowest SEP category (**Figure 5.2A**), although it is possible to identify a subset of households with a higher score in the index excluding the lowest SEP categories, presumably because these households are in one or more of these lowest categories and so get a zero score for this/these indicator(s) instead of a negative score. The separation between the index including all categories and the index excluding the lowest frequency category is somewhat more marked.

In Brazil, there is considerable scatter between the wealth index including all categories and the index excluding the lowest SEP categories (**Figure 5.2B**). The scatter between the index including all categories and the index excluding the lowest frequency indicators is much less, but it is still possible to identify subsets of households given different scores in the two indices.

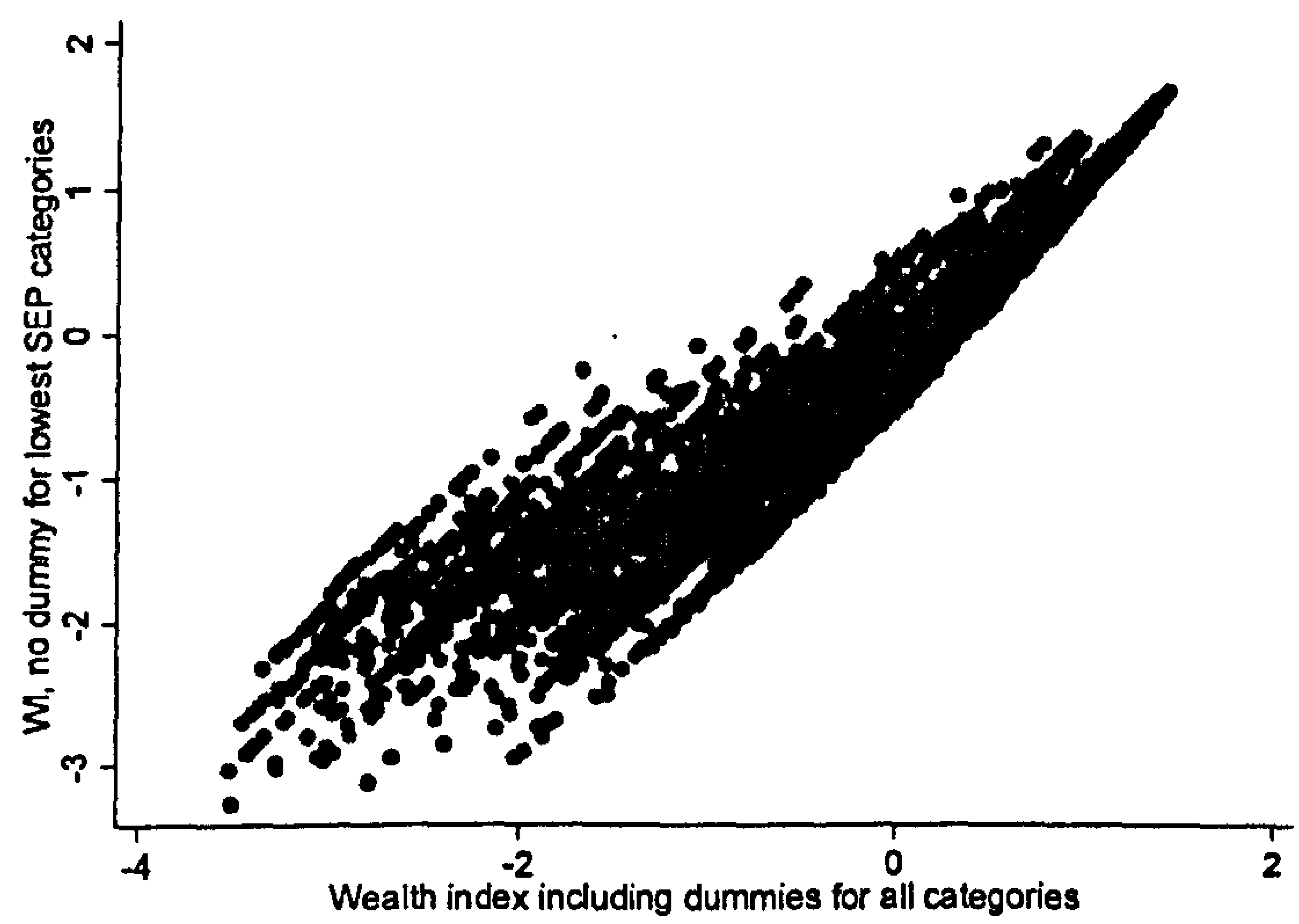
Figure 5.2: Scatter plots of the relationship between wealth indices including all categories of categorical variables or omitting one dummy variable

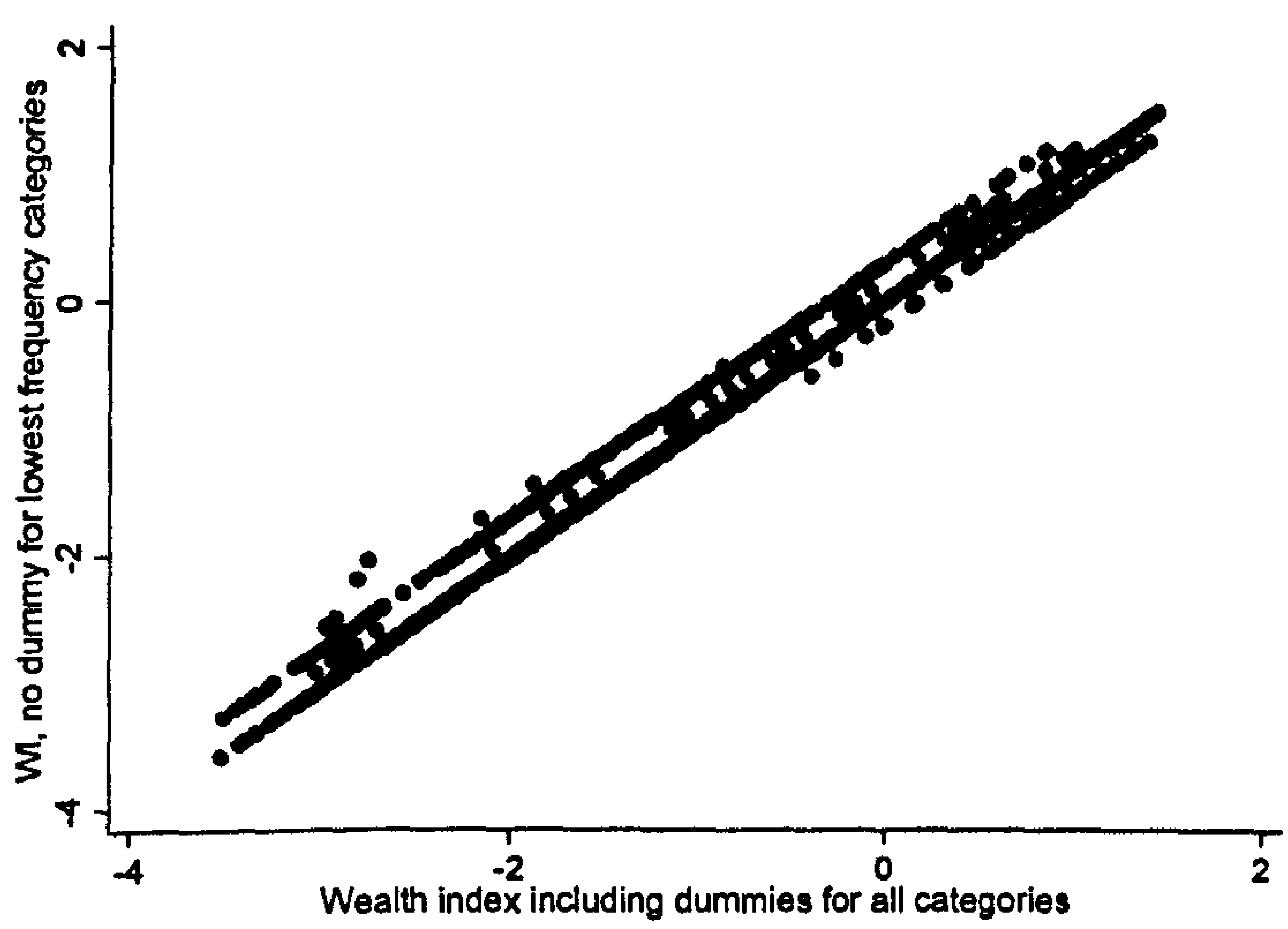
A: Malawi





B: Brazil





Excluding the lowest SEP category of categorical variables results in considerable differential misclassification compared with the index including all categories, in both Malawi and Brazil (**Table 5.4**). The extent of differential classification is greater in Malawi, with just 61% of households being in the same quintile across the two indices. This presumably reflects the higher proportion of households in the lowest SEP categories of the variables in Malawi compared with Brazil. In contrast, agreement is very high between the wealth index including all categories and the index excluding the lowest frequency categories in both Malawi and Brazil. Since just one dummy variable for each categorical variable must be omitted to avoid the problems of complete linear dependence between dummy indicators, these results suggest that the linear dependence introduced by including dummy variables for all categories of categorical variables is not particularly problematic. Binary indicators, however, are used with a single indicator rather than an indicator for both 'yes' and 'no' responses; the negative response, i.e. lowest SEP category, is always omitted from the PCA. The inclusion of all categories or the omission of the lowest frequency category therefore means that binary and categorical variables are treated inconsistently. This raises the question of whether the correct approach is to exclude the lowest SEP category. In order to better answer this question, it is useful to examine the weights assigned to the indicators by the different approaches.

Table 5.4: Extent of differential classification between quintiles of wealth indices; comparisons with the wealth index including dummy variables for all categories of categorical variables

Number of quintiles moved	*Proportion of households*	
	Excluding lowest SEP category	*Excluding lowest frequency category*
Malawi		
0	0.61	0.97
1	0.27	0.03
2	0.11	0
3	0.008	0
4	0	0
Kappa (SE)	*0.52 (0.005)*	*0.98 (0.005)*
Brazil		
0	0.83	0.99
1	0.17	0.01
2	0	0
3	0	0
4	0	0
Kappa (SE)	*0.78 (0.004)*	*0.98 (0.004)*

Note that in order to investigate the influence of the subjective decisions regarding the choice of lowest SEP category, a further index was constructed in the Malawi data excluding alternative categories for water source and cooking fuel (communal hundpump/well and collected firewood respectively). These two indicators were those that received the lowest weights in the index including all categories, but were different from those selected on subjective substantive grounds to be the lowest SEP category. The agreement of this index with the wealth index including dummy variables for all categories was almost identical to the agreement of the index presented above where lowest category variables were selected intuitively rather than statistically (data not shown).

Weights assigned to the indicators

With the exception of minor differences, the weights assigned to binary indicators were similar across the three wealth indices in both countries (data not shown). The weights assigned to categorical variables, however, demonstrated some important differences across the indices (**Table 5.5**). When using PCA to construct a wealth index, it is vital that the weights assigned to indicators make sense substantively. Both the exclusion of the lowest SEP categories and the exclusion of the lowest frequency categories result, in certain circumstances, in counter-intuitive weights. In Malawi, the lowest SEP toilet facility was designated as none/other facility; in the index excluding the lowest SEP category this therefore has zero weighting. In this index, however, traditional latrine with roof and traditional latrine with no roof are both assigned a negative weight, because of their negative association with the other indicators of high SEP included in the PCA. This index therefore implies that having a traditional latrine is *worse* for your SEP than having no toilet facility at all. An example of how excluding the lowest frequency categories can also result in counter-intuitive weights is provided by the weights for water source in Malawi. In this case, the lowest frequency category is water piped into dwelling, which therefore has zero weight. This means that having water piped into your dwelling has a lower weight, and is therefore an indicator of lower SEP, than other water sources such as using water piped to somewhere other than your dwelling, or using a communal standpipe. It is thus clear that each method of constructing the wealth index can result in important, and sometimes nonsensical, differences in the implicit socio-economic ordering of categories.

Table 5.5: Weights assigned to the indicators of categorical variables for different methods of wealth index construction

	Index including all dummies	*Index excluding lowest SEP category*	*Index excluding lowest frequency dummy*
Malawi			
Drinking water source			
Piped into dwelling	0.2762	0.3132	0
Piped outside dwelling	0.1630	0.1663	0.1873
Communal standpipe	0.1250	0.1211	0.1527
Personal handpipe/well	0.0154	0.0134	0.0203
Communal handpipe/well	-0.2269	-0.2439	-0.2460
River/spring/lake/other	-0.0433	0	-0.0467
Toilet facility			
Flush toilet	0.2760	0.3104	0.2506
VIP latrine	0.0893	0.0852	0
Traditional latrine with roof	0.0014	-0.0239	0.0245
Traditional latrine no roof	-0.0611	-0.0631	-0.0659
None or other	-0.0923	0	-0.1041
Cooking fuel			
Collected firewood	-0.3047	-0.3124	-0.3334
Purchased firewood	0.1251	0.1231	0.1467
Paraffin/gas/charcoal	0.2194	0.2184	0.2478
Electricity	0.2452	0.2783	0.2239
Crop residue/sawdust/other	0.0042	0	0
Material of dwelling floor			
Sand	-0.0078	-0.0349	0
Smoothed mud/other	-0.3116	0	-0.3376
Smoothed cement/wood/tiles	0.3313	0.3063	0.3573

	Index including all dummies	*Index excluding lowest SEP category*	*Index excluding lowest frequency dummy*
Brazil			
Water source			
piped into residence	0.2471	0.2643	0.2462
piped in yard /plot	-0.0930	-0.1227	-0.0963
well /spring inside	-0.1230	-0.1616	-0.1278
well /spring outside	-0.1575	0	-0.1622
bottled water	0.0669	0.0796	0.0679
other water	-0.1200	-0.1203	0
Toilet facility			
toilet to sewer	0.2335	0.2810	0.2367
toilet to open space	-0.0456	-0.0698	-0.0464
toilet to river /lake	-0.0094	-0.0185	-0.0097
latrine to sewer	0.0712	0.0761	0.0710
latrine no-connected	0.0095	-0.0225	0.0081
traditional latrine	-0.0863	-0.1421	-0.0888
no toilet facility	-0.2818	0	-0.2813
other toilet	-0.0099	-0.0098	0
Floor material			
earth /sand floor	-0.2240	0	-0.2240
wood planks floor	0.0017	-0.0282	-0.0001
polished wood floor	0.0837	0.0832	0.0838
vinyl floor	0.0310	0.0374	0
ceramic tiles floor	0.2219	0.2738	0.2255
cement floor	-0.1643	-0.2290	-0.1662
carpet floor	0.0769	0.0934	0.0781
other floor	-0.0182	-0.0136	-0.0171
Wall material			
palm, straw walls	-0.0627	-0.0616	-0.0635
mud unpolished walls	-0.2057	0	-0.2059
raw wood walls	-0.0835	-0.1197	-0.0864
alvenaria (finished) walls	0.1922	0.2269	0.1965
polished wood walls	-0.0488	-0.1050	-0.0526
other walls	-0.0100	-0.0126	0
Roof material			
palm /straw roof	-0.1367	-0.1180	-0.1376
raw wood roof	-0.0191	-0.0284	-0.0201
clay tiles roof	-0.2102	0	-0.2118
concrete roof	0.2634	0.3087	0.2674
zinc roof	-0.0402	-0.0781	-0.0424
polished wood roof	0.0628	0.0417	0.0617
eternit, amianto roof	-0.0137	-0.0540	-0.0155
other roof	-0.0226	-0.0268	0

Effect on agreement with consumption expenditure

Alternative methods of using dummy variables in PCA have little effect on analyses using the wealth index in Malawi. The agreement of the wealth index with consumption expenditure is very similar using the wealth indices constructed with and without dummy variables for the lowest SEP and lowest frequency categories of categorical variables, compared with the index including all categories (**Table 5.6**).

Table 5.6: Agreement with consumption expenditure of wealth indices constructed with and without dummy variables for all categories of categorical variables

Number of quintiles moved	*Percentage of households*		
	Index including dummy variables for all categories	*Excluding lowest SEP category*	*Excluding lowest frequency category*
0	29.0	28.1	29.0
1	34.9	34.0	35.2
2	21.6	22.4	21.2
3	11.6	12.1	11.8
4	2.9	3.5	2.8
Kappa	*0.11 (p<0.001)*	*0.098 (p<0.001)*	*0.11 (p<0.001)*

5.4.4.2 Alternative methods of dealing with categorical variables

Index distributions and weights assigned to indicators

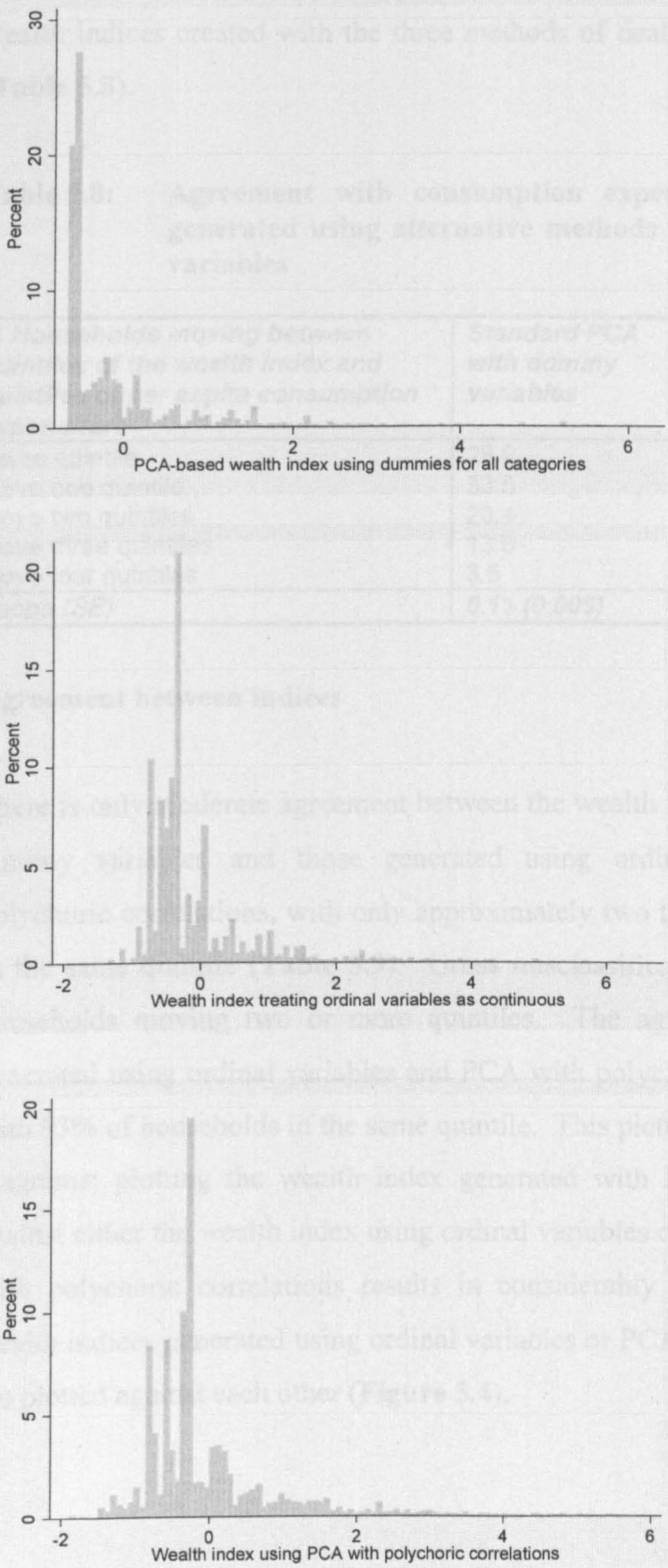
The weights assigned to the indicators using the three methods of dealing with categorical variables are shown in **Table 5.7**. Note that while the use of ordinal variables implicitly causes categories of a variable to be equally spaced, this is not the case when either dummy variables or ordinal variables are used.

The wealth indices generated using PCA with ordinal variables and PCA with polychoric correlations have very similar distributions. There are, however, notable differences between these and the distribution of the wealth index using PCA with dummy variables. The index created using dummy variables exhibits more marked clumping at lower values than the other two indices (**Figure 5.3**).

Table 5.7: Weights assigned to the indicators using alternative methods of dealing with categorical variables

	Using dummy variables	*Using ordinal variables*	*Using PCA with polychoric correlations*
Drinking water source		0.3885	
Piped into dwelling	0.2762		0.7232
Piped outside dwelling	0.1630		0.5392
Communal standpipe	0.1250		0.3434
Personal handpipe/well	0.0154		0.2240
Communal handpipe/well	-0.2269		-0.0752
River/spring/lake/other	-0.0433		-0.5670
Toilet facility		0.2909	
Flush toilet	0.2760		0.6398
VIP latrine	0.0893		0.4935
Traditional latrine with roof	0.0014		0.1340
Traditional latrine no roof	-0.0611		-0.1793
None or other	-0.0923		-0.4290
Cooking fuel		0.4080	
Collected firewood	-0.3047		0.8275
Purchased firewood	0.1251		0.5583
Paraffin/gas/charcoal	0.2194		0.3396
Electricity	0.2452		0.2360
Crop residue/sawdust/other	0.0042		-0.1437
Material of dwelling floor		0.3564	
Sand	-0.0078		-0.7796
Smoothed mud/other	-0.3116		-0.0964
Smoothed cement/wood/tiles	0.3313		0.47889
Electricity			
Yes	0.3426	0.4138	0.7789
No			-0.0513
Television			
Yes	0.2835	0.3548	0.8043
No			-0.0354
Radio			
Yes	0.0194	0.0333	0.0251
No			-0.0307
Bicycle			
Yes	0.0026	0.0157	0.0386
No			-0.0221
Motorbike			
Yes	0.0432	0.0610	0.5270
No			-0.0037
Car			
Yes	0.1887	0.2379	0.8637
No			-0.0136
Domestic servant			
Yes	0.1425	0.1850	0.6586
No			-0.0148
Own agricultural land			
Yes	-0.2279	-0.2793	-0.0552
No			0.4012

Figure 5.3: Distribution of wealth indices generated with alternative methods for dealing with categorical variables



Agreement with consumption expenditure

The level of agreement with consumption expenditure does not differ between the wealth indices created with the three methods of dealing with categorical variables (**Table 5.8**).

Table 5.8: Agreement with consumption expenditure for wealth indices generated using alternative methods for dealing with categorical variables

% Households moving between quintiles of the wealth index and quintiles of per capita consumption expenditure	*Standard PCA with dummy variables*	*Standard PCA with ordinal variables*	*PCA with polychoric correlations*
Same quintile	28.9	29.4	29.7
Move one quintile	33.5	34.8	34.5
Move two quintiles	20.4	21.9	21.6
Move three quintiles	13.6	11.0	11.1
Move four quintiles	3.6	2.9	3.1
Kappa (SE)	*0.11 (0.005)*	*0.11 (0.005)*	*0.12 (0.005)*

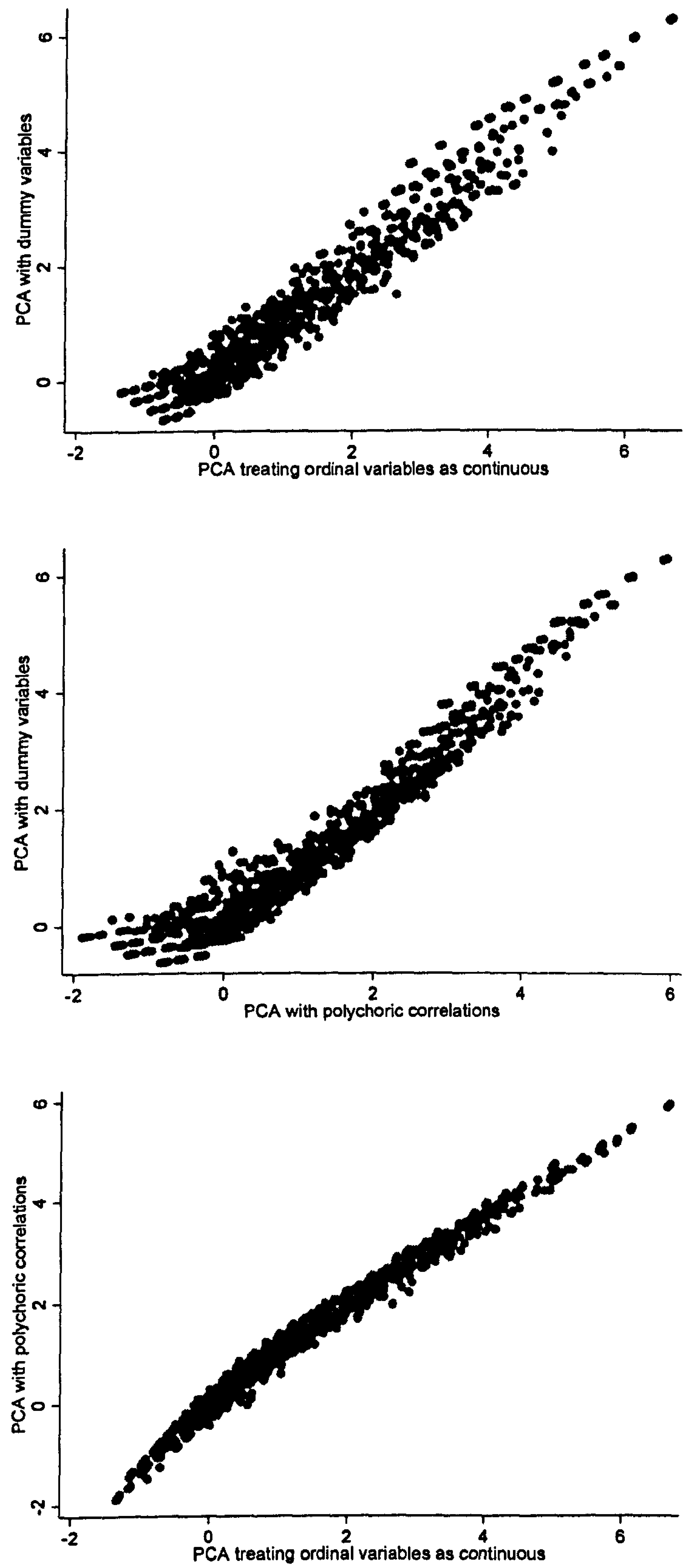
Agreement between indices

There is only moderate agreement between the wealth index created using PCA with dummy variables and those generated using ordinal variables or PCA with polychoric correlations, with only approximately two thirds of households classified in the same quintile (**Table 5.9**). Gross misclassification is rare, with only a few households moving two or more quintiles. The agreement between the indices generated using ordinal variables and PCA with polychoric correlation is very high, with 93% of households in the same quintile. This picture is confirmed by the scatter diagrams; plotting the wealth index generated with PCA using dummy variables against either the wealth index using ordinal variables or the wealth index using PCA with polychoric correlations results in considerably more scatter than when the wealth indices generated using ordinal variables or PCA with polychoric correlations are plotted against each other (**Figure 5.4**).

Table 5.9: Agreement between wealth indices generated using alternative methods for dealing with categorical variables

Wealth indices being compared	*% Households moving between quintiles*				
	Same quintile	*Move 1 quintile*	*Move 2 quintiles*	*Move 3 quintiles*	*Move 4 quintiles*
PCA with dummy variables and PCA with ordinal variables	67.1	26.0	5.3	1.5	0
PCA with dummy variables and PCA with polychoric correlations	66.2	23.9	8.1	1.8	0
PCA with ordinal variables and PCA with polychoric correlations	92.6	6.0	1.4	0	0

Figure 5.4: Scatter plots of wealth indices generated using alternative methods for dealing with categorical variables



5.4.5 Discussion

Despite concerns about the colinearity between dummy variables of categorical variables when all categories are included in PCA, this appears to have little impact on the final wealth index. Wealth indices using dummy variables for all categories had very strong agreement with wealth indices excluding the dummy variables for the lowest frequency categories in both Malawi and Brazil. There are, however, flaws with each way of using dummy variables in PCA: i) each method can potentially result in counter-intuitive weights or ordering of categories, ii) including all dummy variables or omitting the lowest frequency category is inconsistent with the treatment of binary indicators, and iii) this method has been shown by Kolenikov & Angeles to be inferior to alternative ways of dealing with categorical variables.[293] I have shown here that there is only modest agreement between a wealth index created using PCA with dummy variables and one created with PCA using ordinal variables or PCA with polychoric correlations. Using the inappropriate dummy variable method is resulting in non-negligible differential classification compared with appropriate methods. In line with the conclusions of Kolenikov & Angeles, classification was very similar between the wealth indices using PCA with ordinal variables and using PCA with polychoric correlations.

My primary recommendation is that PCA with dummy variables should not be used to construct wealth indices. Given the similar results between using ordinal variables in standard PCA and using PCA with polychoric correlations, and the fact that PCA with polychoric correlations is more computationally intensive, I would advocate the use of PCA with ordinal variables treated as continuous. This does require the establishment of an ordinal structure for the categorical variables, which may not be straightforward, particularly for secondary data analysis where the researcher may have less in-depth knowledge about the setting. I would argue, however, that if the variables are meaningful indicators of SEP it is not unreasonable that they should be able to be placed in a sensible hierarchy with regard to their hypothesised relationship with SEP. This decision on the ordinal structure of the data should be context-specific and should be carried out with knowledge of the local importance of each category, preferably prior to data collection. The mean level of another SEP indicator, e.g. education, across categories could also be used to inform the proposed ordinal structure of the indicators where necessary. The next section of this chapter will introduce the method of Multiple Correspondence Analysis, which is a potential alternative to PCA for when it is not possible to assign an ordinal structure to the indicators.

One of the main purposes of this thesis is to investigate the wealth index as it is currently used by the majority of researchers. For this reason, much of the analysis in the rest of this thesis will continue to use the dummy variable (including all categories) approach to constructing a wealth index with PCA.

5.5 Exploring alternative weighting methods

5.5.1 Background

The limitations of PCA for the construction of wealth indices are twofold: i) PCA is inappropriate for use with the discrete data commonly included in a wealth index, and ii) the first principal component frequently explains only a low proportion of the total variation in asset data. As we saw in the previous section, there is concern that using dummy variables for categorical variables introduces spurious correlations between the indicators, and that all methods of dealing with nominal variables in PCA are flawed. Although using ordinal variables as continuous terms in standard PCA or using PCA with polychoric correlations provide suitable options for using ordered categorical variables with PCA, some may consider it impossible or undesirable to force an ordinal structure on the variables. A further concern is that PCA is a fairly complex method. It is likely to be unfamiliar and poorly understood by less technical readers of papers. There could, therefore, be an argument that simpler, more transparent and easily understood methods for weighting the items in a wealth index would be preferable. Using an equal weights approach (simple sum) was used in several early studies using wealth indices.[298, 299] Although simple, this approach could be criticised for being arbitrary and simplistic, since different assets are unlikely to have equal meaning in terms of SEP. There is some evidence that PCA performs no better as a proxy for consumption expenditure than an equal weights approach.[284] In contrast, Bollen *et al.* showed that a PCA-based wealth index and an equal weights index had considerably different regression coefficients with consumption expenditure[300]; another study also demonstrated that a PCA-based wealth index had a stronger relationship than an equal weights index with a latent variable of permanent income (planned and anticipated income; a long-term concept of SEP that both consumption expenditure and wealth indices have been claimed to be measuring).[94]

Another potentially simpler and more easily understood alternative to PCA is to use the inverse of the proportion of households that own an asset as its weight. This is based on a method originally suggested by Townsend.[301] The underlying assumption is that assets owned by a smaller proportion of households are indicative of higher household wealth and are therefore assigned a higher weight.[302] A problem with methods using inverse proportion weights is that not all assets show a linear relationship with living standards, e.g. ownership of a motorbike may tend to increase up to a certain income and subsequently decrease in richer households.[56] A similar method was applied by Morris *et al.*, who calculated weights by using the inverse of the proportion of households that owned each item, multiplying that by the number of units of asset owned by the household, and summing this quantity for all assets.[32] Both the equal weights and the inverse proportion weighting methods can only be applied to binary data.

Multiple Correspondence Analysis (MCA) is analogous to PCA, but is used for discrete data.[303] Whilst this method does not remove the complexity and unfamiliarity of PCA, nor the problems of the first dimension explaining a small proportion of the total variance, it is appropriate for the analysis of the categorical data commonly collected on most assets and does not require an ordinal structure to be imposed on the data.[271] Booysen *et al.* utilised MCA to construct wealth indices for seven sub-Saharan African countries. They found that the index was very highly correlated with one constructed using PCA, and that although households were not always in the same quintile by the two indices, movement was in most cases limited to one quintile in either direction. They also showed that the weights assigned to index items were generally similar by the two methods.[271]

Other methods for weighting items in a wealth index do exist, but in general offer neither more simplicity than PCA, nor more suitability for discrete data. For instance, latent variable approaches have been proposed.[65, 285] In his 2005 paper, Montgomery constructs a wealth index using a latent variable approach called MIMIC; this model specifies which variables are determinants of living standards (e.g. education and occupation) and which are indicators of living standards (e.g. consumer durables). In other methods of wealth index construction, both determinants and indicators of the underlying socio-economic construct may be included without distinction. For instance, producer durables such as farm equipment are sometimes included in a wealth index in the same way as consumer durables, whereas these should in fact be considered as determinants of the socio-economic construct and not treated in the same way as indicator variables.[65] Latent variable methods, despite offering some theoretical advantages over PCA, are far more complex and arguably even less easily understood by a wide readership than PCA. A further option could be to assign weights based on the price of an item, but this requires detailed information allowing for date of purchase, area of purchase, and current condition of the item. There is also some evidence that price-based indices are less reliable than alternatives; one study showed a price-based index to have implausible relationships with health outcomes[304] and a further study demonstrated that two price methods had weaker relationships with a permanent income latent variable than alternative weighting methods.[94] In contrast, however, Morris *et al.* showed high correlation between wealth indices constructed using the inverse proportion method and weights based on the current value of each item.[32] The issue of prices is a crucial one. Consumption expenditure measures are adjusted for the variability of prices across regions. In contrast, the variability in prices is generally ignored when pooling data across regions to construct a wealth index. The methods currently used in the literature to incorporate prices into weights for wealth index indicators (typically relying on self-reported current sale value) do not, however, appear to be appropriate, and more complex methods involving regional price data calculation similar to the approach used for consumption expenditure data would probably be too costly for the majority of epidemiological studies.

5.5.2 Aim

The aim of these analyses was to compare wealth indices constructed using different weighting methods to identify whether PCA offers an advantage over either simpler, more transparent methods (equal weights and inverse of the proportion of the population owning the asset) or methods more appropriate for discrete data (MCA).

5.5.3 Methods

Wealth indices were constructed using the core assets within the IHS2. The following methods were used to weight the data:

1. Using PCA including all dummy variables for each category of categorical variables
2. Using PCA but with dichotomised versions of all categorical variables
3. Applying equal weights to binary variables
4. Weighting binary variables by the inverse of the proportion of the population which owns that item
5. Using MCA including all categories of categorical variables

Applying equal weights and using the inverse of the proportion of the population that owns each item can only be carried out using binary variables. Therefore for the purposes of creating Indices 3 and 4, each categorical variable was collapsed to a binary variable, based on a subjective assessment of the most appropriate dichotomisation resulting in an appropriate distribution of ownership and meaningful categories (**Box 5.1**). The detailed entries for observations coded as 'other' were examined in order to determine the most appropriate way to classify the 'other' group. In addition to using these binary variables for Indices 3 and 4, Index 2 was created in order to explore its agreement with Index 1, and to facilitate a more direct comparison of the PCA approach with the simpler weighting methods used in Indices 3 and 4.

Indices were standardised to give a mean of zero and a variance of one. Survey analysis was used for descriptive analyses to adjust for the complex sampling used in IHS2. Sampling weights cannot be applied during MCA and PCA; therefore in order to facilitate comparisons, sampling weights were not used when calculating the weights for any index but they were used for generating quintiles, as in previous studies.[290, 305]

The PCA-based indices utilised the weights from the first principal component to ascertain the weights.

Box 5.1: Details of dichotomisation of categorical variables

Floor material:
- Lower SEP group: sand, smoothed mud
- Higher SEP group: smooth cement, tile, other

Cooking fuel:
- Lower SEP group: firewood, crop residue, other
- Higher SEP group: paraffin, electricity, charcoal

Water supply:
- Lower SEP group: personal open unprotected well, communal open unprotected well, river, spring, lake, reservoir, other
- Higher SEP group: piped into dwelling, piped outside dwelling, communal standpipe, personal handpump, communal handpump, protected spring

Toilet facility:
- Lower SEP group: no toilet facility, other
- Higher SEP group: flush toilet, VIP latrine, traditional latrine with roof, latrine without roof

A Stata macro for MCA was downloaded from the EconPapers website.[306] In a similar manner to PCA, the weights used are those identified from the first dimension of the MCA. However, unlike PCA, the MCA command is not compatible with post-estimation commands in Stata. Thus in order to apply the weights, a score variable was manually generated applying the appropriate weight from the MCA to each indicator.

The distribution of each index was examined graphically to assess the extent of skewness and clumping. Agreement between indices was assessed by misclassification of households between quintiles of indices and Kappa statistics. Furthermore, the relationships between indices were assessed graphically, using scatter diagrams when comparing two indices using categorical data or box-plots when comparing one or more index constructed using binary variables. In addition to comparisons between the indices, each index was compared with per capita consumption expenditure, which was taken as a gold standard measure of SEP.

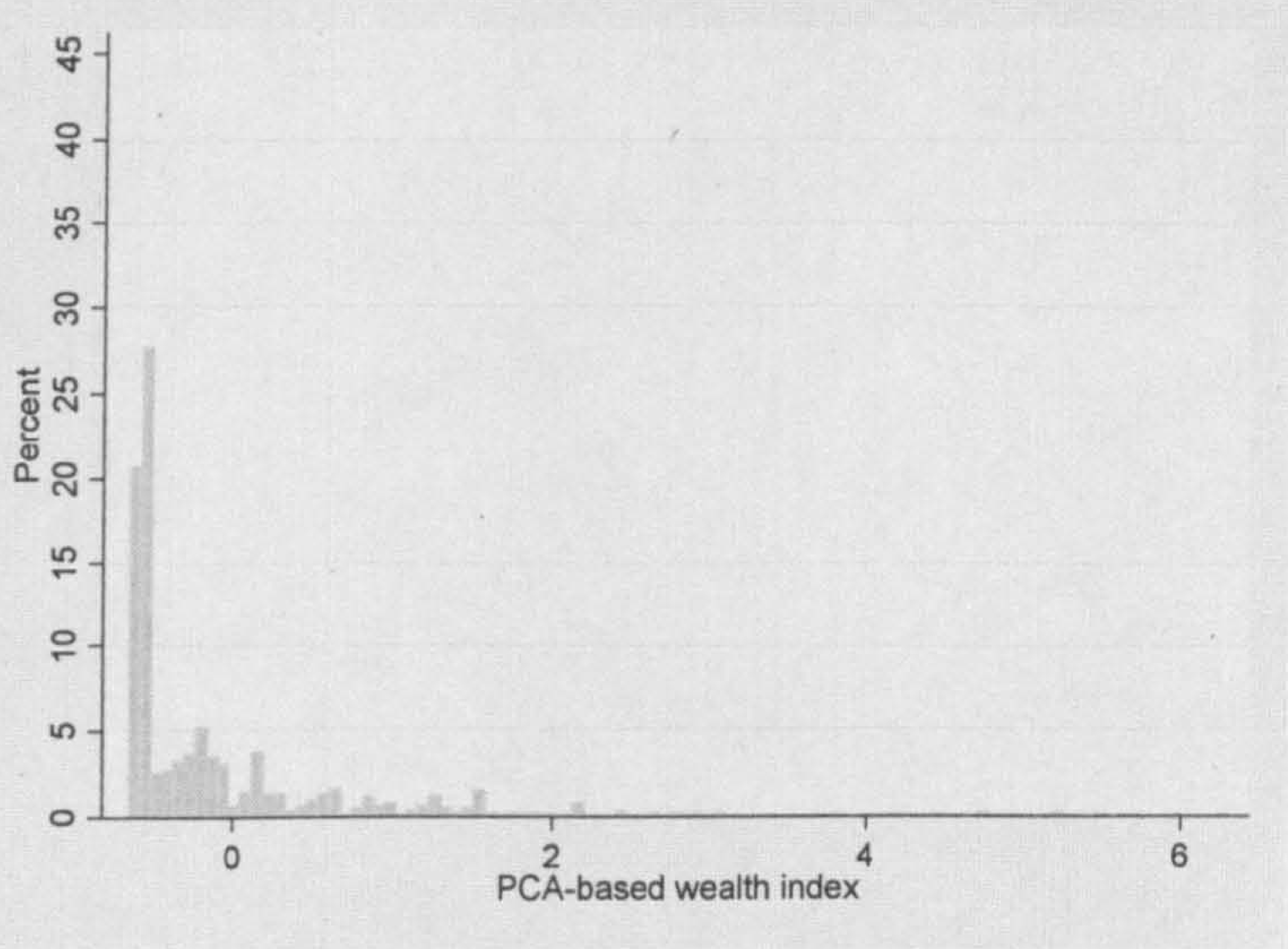
5.5.4 Results

5.5.4.1 Distribution of Indices

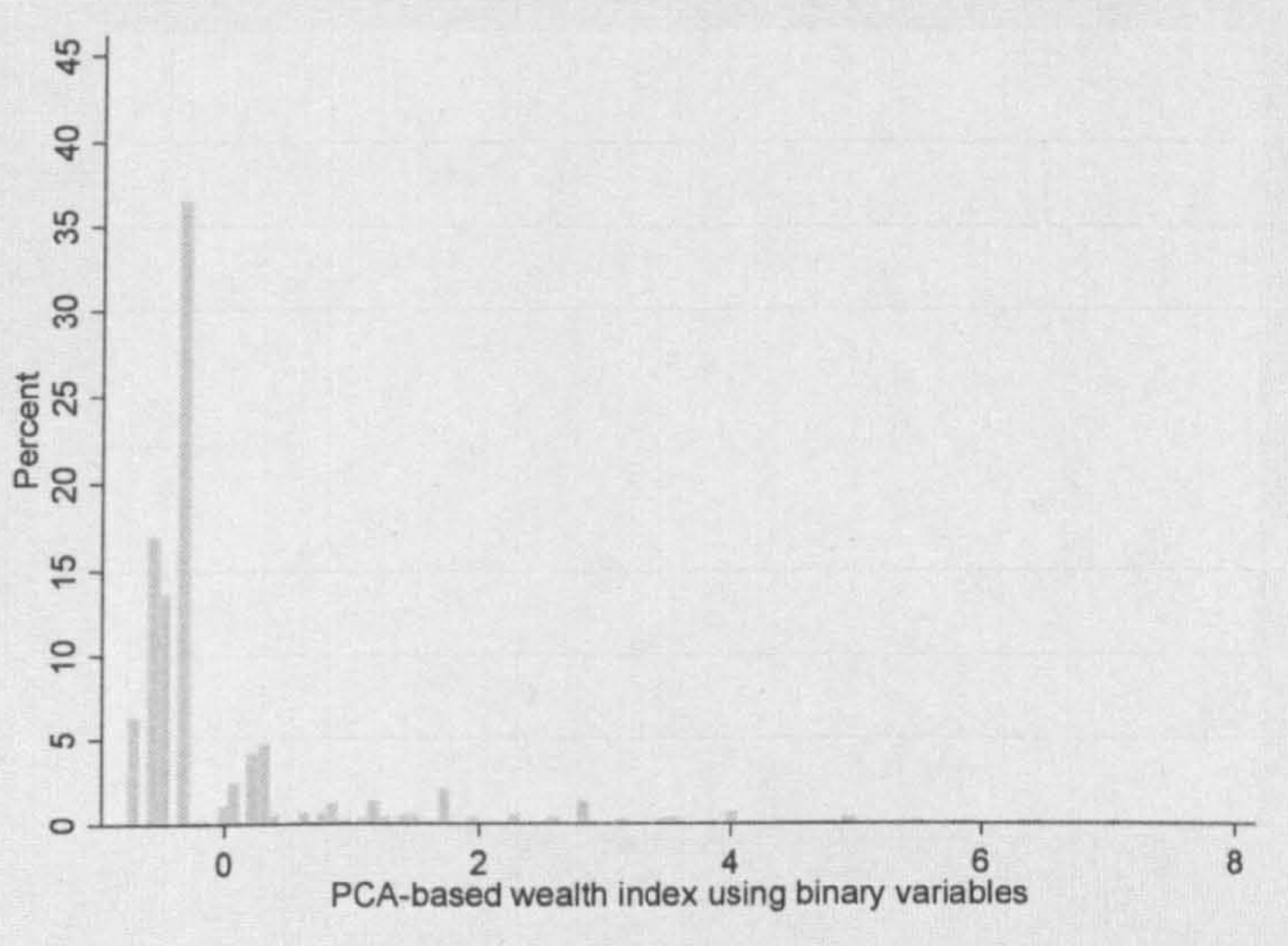
Figure 5.5 shows histograms of the five wealth indices. Apart from Index 3 (equal weights), all indices were highly right-skewed. Index 3 was less skewed, but had severe clumping, with the score taking just 20 unique values compared with several thousand for the other indices. All indices demonstrated clumping, with many households having the same or very similar scores at the lower end of the spectrum. Clumping was more severe in indices using binary variables, with indices 2 and 4 demonstrating more clumping than indices 1 and 5.

Figure 5.5: The distribution of scores taken by indices

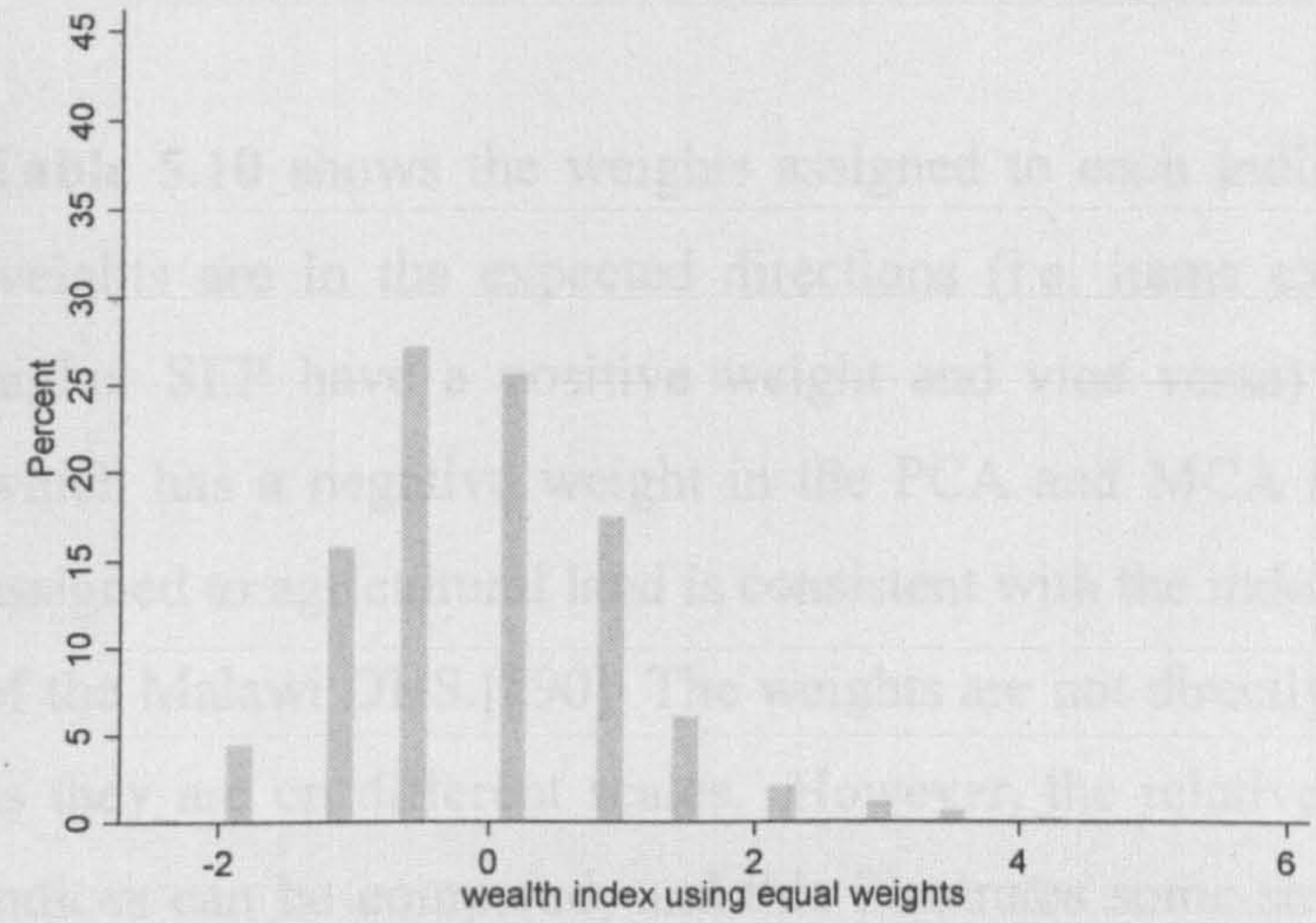
1. PCA-based index



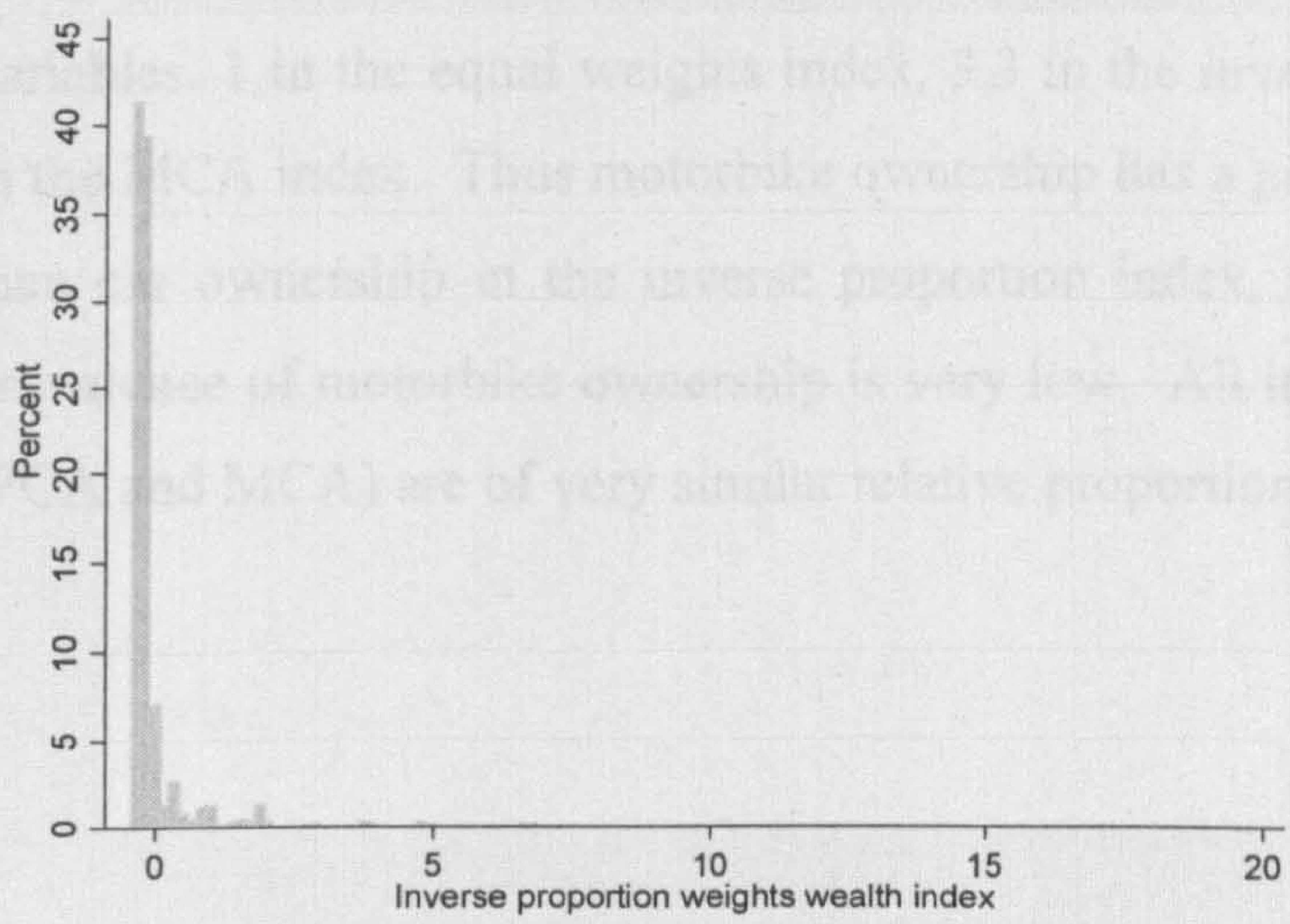
2. PCA-based index using binary variables



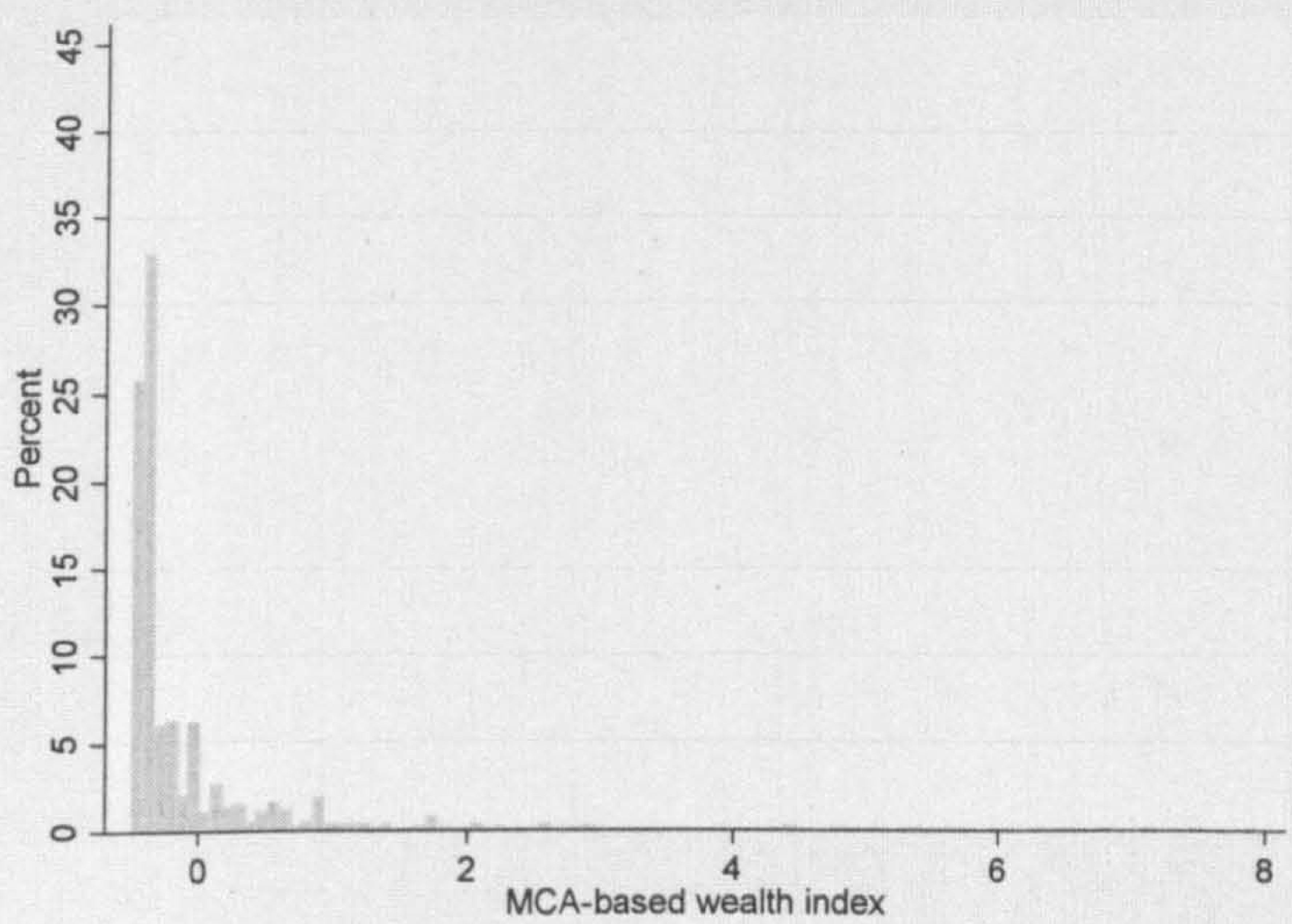
3. Equal weights



4. Inverse proportion



5. MCA



5.5.4.2 Weights assigned to index components

Table 5.10 shows the weights assigned to each indicator in the five indices. All weights are in the expected directions (i.e. items expected to be associated with higher SEP have a positive weight and vice versa) apart from agricultural land, which has a negative weight in the PCA and MCA indices. The negative weight assigned to agricultural land is consistent with the index used in World Bank analysis of the Malawi DHS.[290] The weights are not directly comparable between indices, as they are on different scales. However, the relative magnitude of weights across indices can be compared, and this illustrates some striking differences between the indices. For instance, the ratio of the weight assigned to a motorbike to the weight assigned to a car is 0.23 in the PCA index, 0.26 in the PCA index using binary variables, 1 in the equal weights index, 3.3 in the inverse proportion index and 0.39 in the MCA index. Thus motorbike ownership has a proportionally far higher weight than car ownership in the inverse proportion index, indicative of the fact that the prevalence of motorbike ownership is very low. All item weights in indices 1 and 5 (PCA and MCA) are of very similar relative proportions.

Table 5.10: Weights assigned to each indicator by various methods:

A: Indices using categorical variables:

Item		*Item weight*	
		PCA	*MCA*
Toilet facility:			
Flush toilet		0.2760	2.081
VIP latrine		0.0894	0.515
Traditional latrine with roof		0.0015	-0.019
Latrine no roof		-0.0613	-0.125
None or other		-0.0923	-0.197
Water source:			
Piped inside dwelling		0.2762	2.428
Piped outside dwelling		0.1631	0.857
Communal standpipe		0.1251	0.161
Personal handpump or well		0.0154	0.011
Communal handpump or well		-0.2270	-0.138
River, lake, spring, reservoir, or other		-0.0433	-0.179
Cooking fuel:			
Collected firewood		-0.3049	-0.153
Purchased firewood		0.1252	0.176
Paraffin, gas or charcoal		0.2196	0.721
Electricity		0.2451	2.537
Crop residue, saw dust, or other		0.0043	-0.084
Floor material:			
Sand		-0.0078	-0.168
Smoothed mud or other		-0.3113	-0.154
Smooth cement, wood, or tiles		0.3310	0.613
Electricity:	yes	0.3427	1.6
	no	-	-0.1
Radio:	yes	0.0193	0.007
	no	-	-0.009
TV:	yes	0.2836	1.726
	no	-	-0.070
Bike:	yes	0.0025	0.002
	no	-	-0.001
Car:	yes	0.1885	2.247
	no	-	-0.028
Motorbike:	yes	0.0432	0.869
	no	-	-0.003
Domestic servant:	yes	0.1426	1.32
	no	-	-0.025
Agricultural land:	yes	-0.2280	-0.081
	no	-	0.589

B: Indices using binary variables:

Item	*Item weight*		
	PCA	*Equal weights*	*Inverse proportion*
Toilet facility: some toilet facility	0.1429	1	1.2
Water source: protected source	0.1703	1	1.5
Cooking fuel: more likely to have been purchased	0.4320	1	11.8
Floor material: modern	0.4084	1	5.0
Electricity:	0.4600	1	17.1
Radio:	0.0225	1	1.8
TV:	0.4012	1	25.7
Bike:	0.0014	1	2.8
Car:	0.2766	1	82.3
Motorbike:	0.0725	1	275.1
Domestic servant:	0.2190	1	53.4
Agricultural land:	-0.3072	1	1.1

5.5.4.3 Agreement of the indices with consumption expenditure

All of the indices have similar levels of misclassification between quintiles of the wealth index and quintiles of per capita consumption expenditure, with only approximately 30% of households in the same quintile and Kappa statistics of roughly 0.1 (**Table 5.11**). Index 5 (MCA-based index) has the best agreement with per capita consumption expenditure, and Index 3 (equal weights) the worst agreement, but the differences between indices are small, indicating that their ability to proxy consumption expenditure is similarly modest.

Table 5.11: Movement of households between quintiles of wealth indices and per capita consumption expenditure

% Households moving between quintiles of the wealth index and quintiles of per capita consumption expenditure	*1. PCA index*	*2. PCA index using binary variables*	*3. Equal weights index*	*4. Inverse proportion index*	*5. MCA index*
Same quintile	28.9	28.0	26.6	28.2	29.2
Move one quintile	34.8	36.0	37.8	33.6	34.3
Move two quintiles	21.5	20.6	22.3	22.5	22.1
Move three quintiles	11.6	12.2	10.5	11.3	11.4
Move four quintiles	2.9	3.1	2.8	4.4	3.0
Kappa	*0.11**	*0.10**	*0.082**	*0.10**	*0.12**

*p<0.001

5.5.4.4 Comparing the indices

Table 5.12 shows a matrix of the Kappa statistics and proportion of households classified into the same quintile between pairs of indices, and **Table 5.13** tabulates the movement of households between quintiles of pairs of wealth indices.

Table 5.12: Percentage of households in the same quintile and Kappa statistics of agreement between pairs of indices

	1. PCA	*2. PCA (binary)*	*3. Equal weights*	*4. Inverse proportion*	*5. MCA*
1. PCA	-				
2. PCA (binary)	41.9% κ=0.27*	-			
3. Equal weights	35.9% κ=0.20*	73.6% κ=0.67*	-		
4. Inverse proportion	39.3% κ=0.24*	69.5% κ=0.62*	67.7% κ=0.60*	-	
5. MCA	75.6% κ=0.69*	51.5% κ=039*	40.6% κ=0.26*	43.4% κ=0.29*	-

*p<0.001

Table 5.13: Agreement of classification into quintiles between pairs of wealth indices

Wealth indices being compared	*% Households moving between quintiles*				
	Same quintile	*Move 1 quintile*	*Move 2 quintiles*	*Move 3 quintiles*	*Move 4 quintiles*
Index 1 (PCA all categories) and Index 2 (PCA binary variables)	41.9	41.3	13.3	4.5	0.4
Index 1 (PCA all categories) and Index 3 (Equal weights)	35.9	38.5	18.8	7.1	1.1
Index 1 (PCA all categories) and Index 4 (Inverse proportion)	39.3	39.2	13.3	8.6	0.98
Index 1 (PCA all categories) and Index 5 (MCA)	75.6	18.9	5.8	0.65	0.33
Index 2 (PCA binary variables) and Index 3 (Equal weights)	73.6	18.7	4.5	4.0	0.5
Index 2 (PCA binary variables) and Index 4 (Inverse Proportion)	69.5	23.1	5.6	2.7	0.33
Index 2 (PCA binary variables) and Index 5 (MCA)	51.5	36.3	11.6	1.5	0.36
Index 3 (Equal weights) and Index 4 (Inverse proportion)	67.7	28.8	3.5	0.91	0.37
Index 3 (Equal weights) and Index 5 (MCA)	40.6	38.4	16.4	4.9	1.0
Index 4 (Inverse proportion) and Index 5 (MCA)	43.4	39.8	10.5	6.7	0.90

Comparing Index 1 (PCA) and Index 5 (MCA), which both used categorical variables, approximately 75% of households were in the same quintile in the two indices, with a Kappa statistic of 0.69. For households in different quintiles, movement was generally limited to one quintile, with less than 7% of households moving two or more quintiles.

Agreement between pairs of indices using binary variables (Indices 2, 3 and 4) was also reasonably high, with approximately 70% of households being in the same quintile between two indices and Kappa statistics of approximately 0.6.

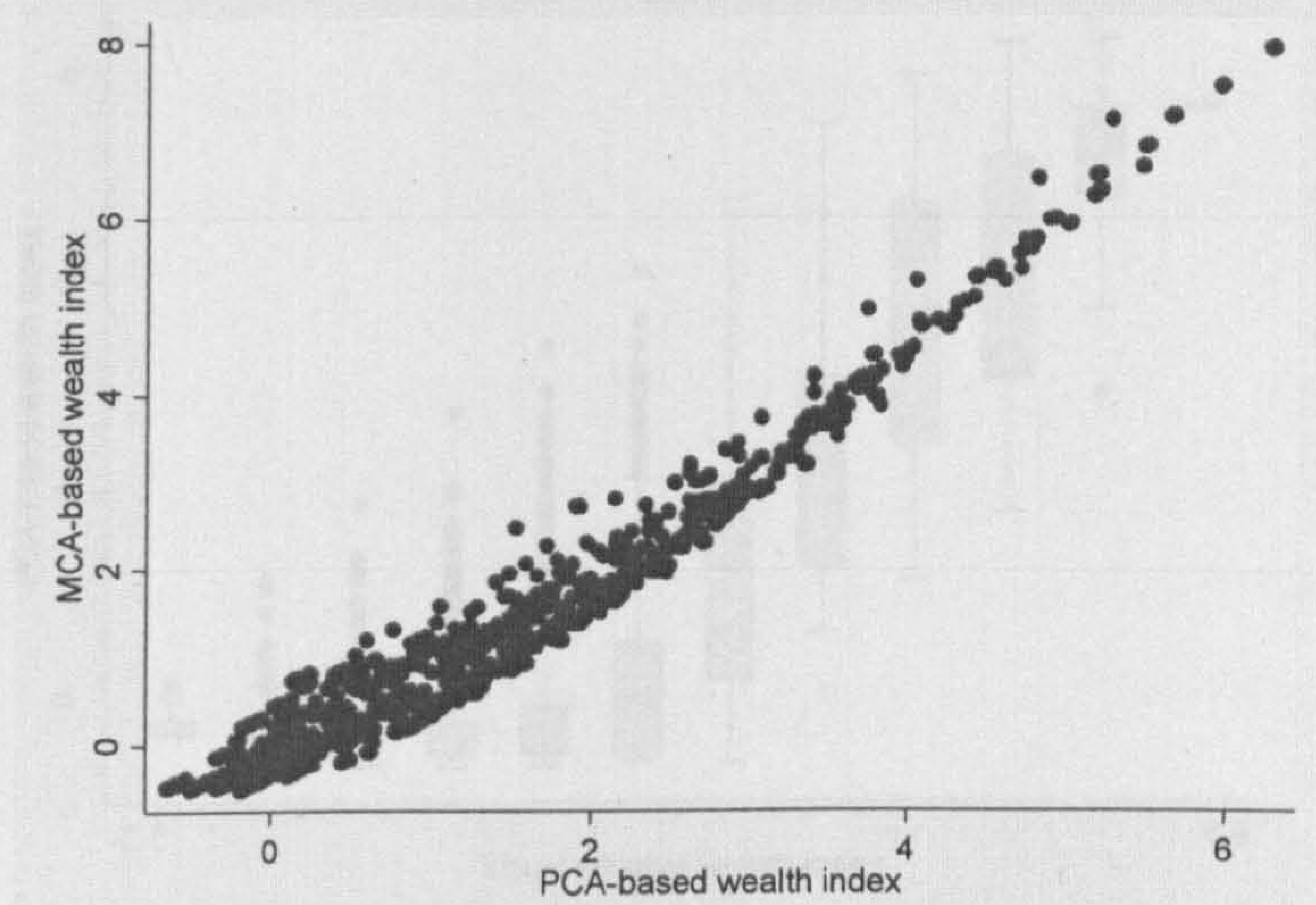
When comparisons were made between an index using categorical variables and an index using binary variables, agreement was weaker. Here, approximately 35-50% of households were in the same quintile between pairs of indices, with Kappa statistics of 0.2-0.4.

Figure 5.6 shows diagrams of the relationship between selected pairs of indices to illustrate key points. These diagrams demonstrate that indices constructed by different weighting methods but using the same form of data (i.e. comparing two indices using categorical variables or comparing two indices using binary variables – **Figures 5.6A** and **B**) showed a reasonably good relationship in comparison with the relationship between pairs of indices constructed using different data (i.e. comparing an index using categorical variables with an index using binary variables – **Figure 5.6C**), which showed considerably more scatter. The scatter between the indices using categorical variables (**Figure 5.6A**) was markedly less than the scatter between the indices using binary variables (**Figure 5.6B**).

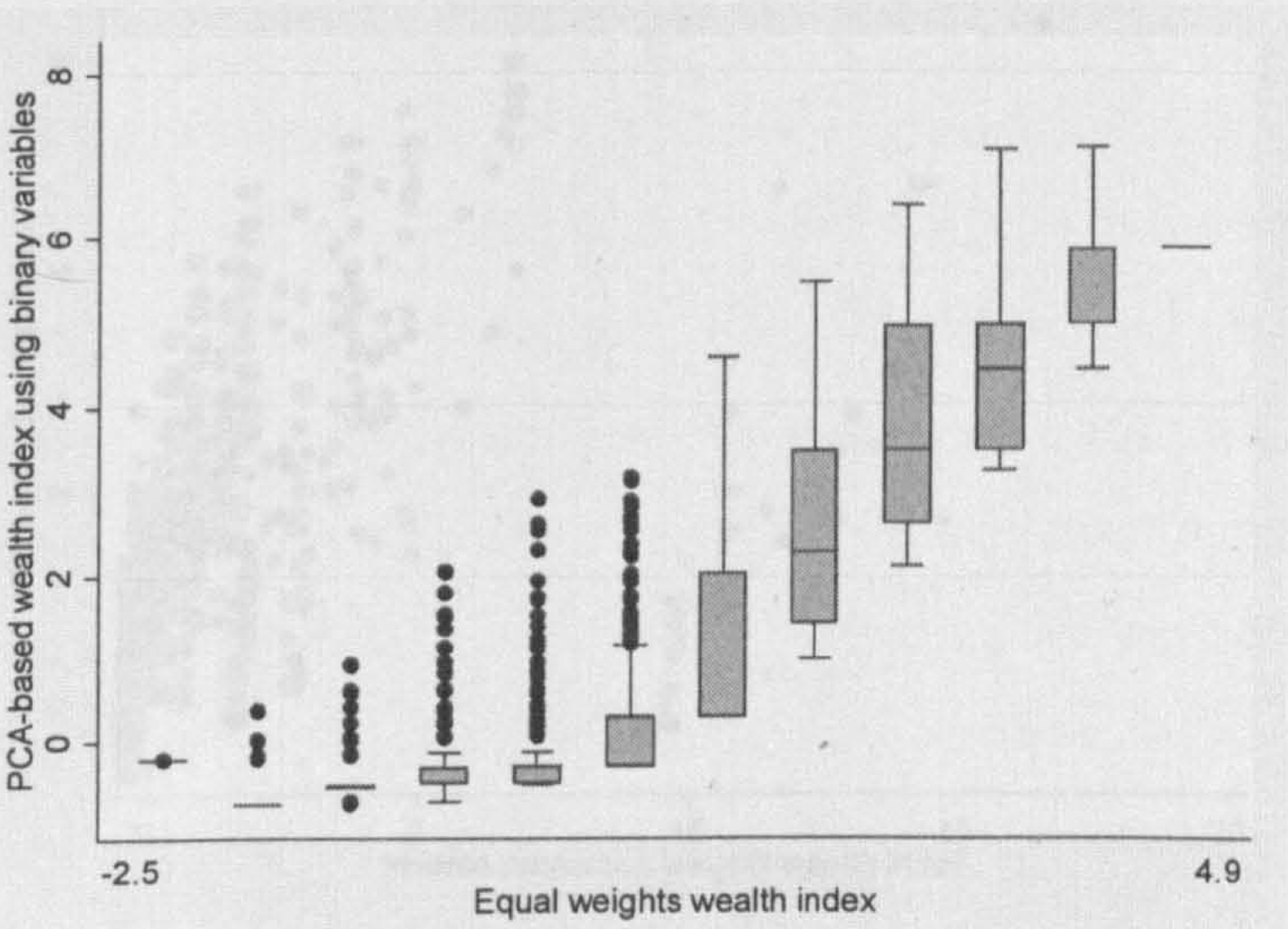
Figure 5.6D demonstrates that Index 4 (Inverse proportion) created a distinct group of households that were ranked substantially higher by the inverse proportion index than by the PCA index. This distinct group was present in comparisons of the inverse proportion index with all other indices. Closer examination of this group of households reveals that they have a significantly higher prevalence of motorbike ownership; 52.6% of households with a score of >9 on the inverse proportion index own a motorbike, compared with 0.36% in the whole population. This demonstrates that when items of very low prevalence are included in an index constructed using the inverse proportion weighting method, the resultant very high weight they are assigned can produce some strange classifications of households.

Figure 5.6: Diagrams showing the associations between some pairs of indices

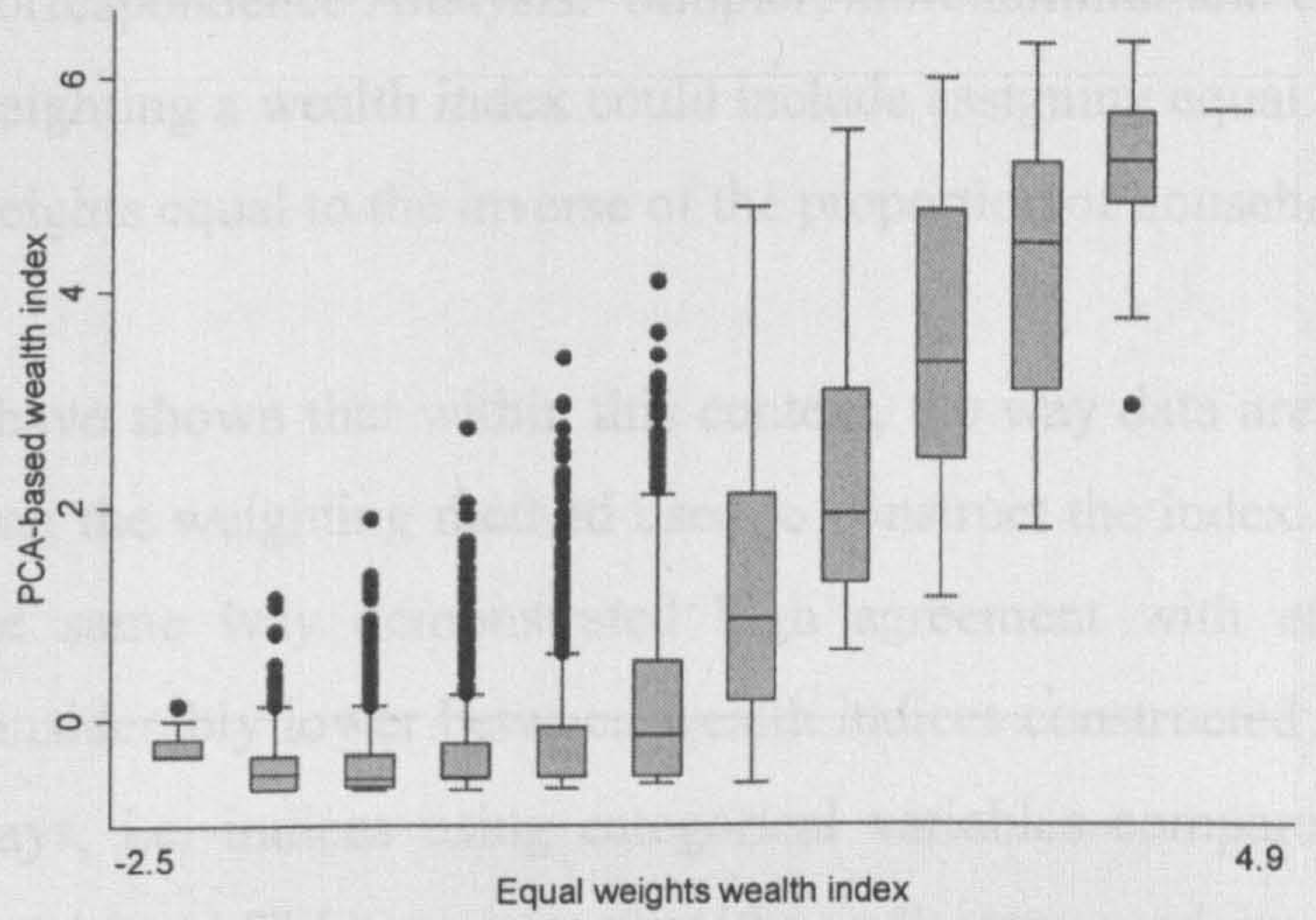
A: Two indices using categorical variables; Index 1 (PCA) and Index 5 (MCA)



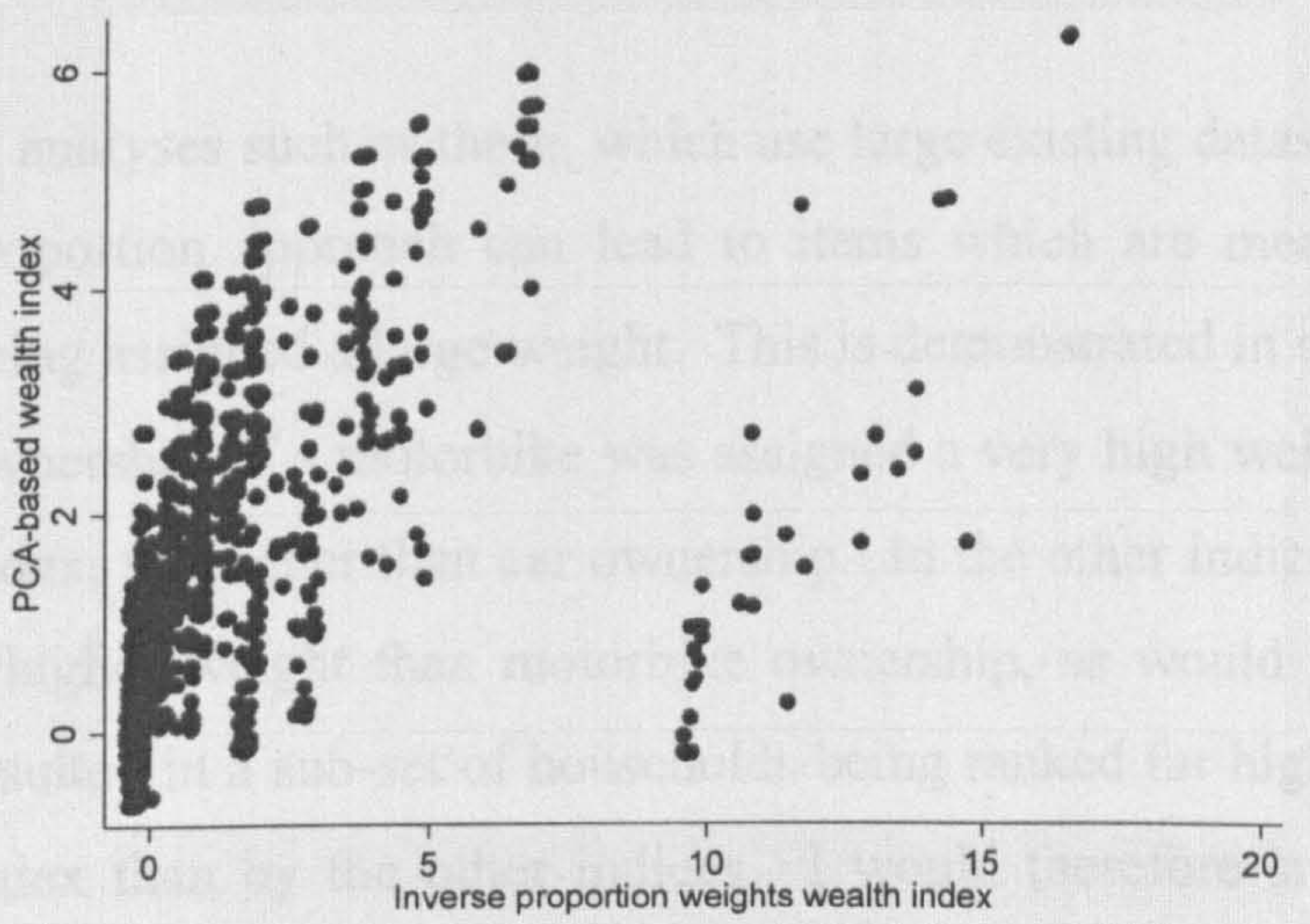
B: Two indices using binary variables; Index 2 (PCA binary) and Index 3 (Equal weights)



C: Index using categorical variables (1: PCA) and index using binary variables (3: Equal weights)



D: Index 1 (PCA) compared with Index 4 (Inverse proportion)



5.5.5 Discussion

The use of PCA to assign weights to assets included in a wealth index has gained significant popularity in recent years. Despite this popularity, this application of PCA remains novel; it is statistically unsuitable for use with the categorical data frequently included in wealth indices, and has not been fully investigated. It is also complex and may hamper the understanding of research using the wealth index approach. **Section 5.4** demonstrated that using ordinal variables as continuous terms in PCA, or using PCA with polychoric correlations are appropriate ways of including ordered categorical variables in PCA. A method that is suitable for discrete data but does not require an ordinal structure to be imposed on the data is Multiple Correspondence Analysis. Simpler, more familiar and easily understood methods for weighting a wealth index could include assigning equal weights to all items, or using weights equal to the inverse of the proportion of households owning the item.

I have shown that within this context, the way data are coded is far more important than the weighting method used to construct the index. Indices using data coded in the same way demonstrated high agreement with each other. Agreement was considerably lower between wealth indices constructed using data coded in different ways, i.e. indices using categorical variables compared with indices using binary variables. This suggests that the indicators used in a wealth index are of great importance, although further work attempting to replicate this finding in other settings would be beneficial.

In analyses such as these, which use large existing datasets, application of an inverse proportion approach can lead to items which are meaningless in a given context being assigned a large weight. This is demonstrated in these analyses by the fact that ownership of a motorbike was assigned a very high weight in the inverse proportion index, far higher than car ownership. In the other indices, car ownership is assigned a higher weight than motorbike ownership, as would probably be expected. This resulted in a sub-set of households being ranked far higher by the inverse proportion index than by the other indices. I would therefore suggest that using the inverse proportion weighting method is only suitable when data collection has been informed by formative research, as it was in Morris' study.[32]

The indices all had similarly modest agreement with consumption expenditure. Within this setting, neither the weighting method used to construct the index, nor the difference between using categorical and binary variables has a strong impact on the ability of a wealth index to proxy consumption expenditure. In terms of the ability of a wealth index to proxy consumption expenditure, PCA appears to offer little advantage over the simpler, more easily understood methods, nor over the more statistically appropriate method of MCA. However, agreement between the indices using the categorical variables and the indices using the binary variables was modest, suggesting that the data included in the wealth index does impact on the final index. While it is not possible to judge whether the indices using categorical data or the indices using binary data are 'better' based on the agreement with consumption expenditure, other features of the data can be used to make this assessment. There will inevitably be some loss of information between categorical and binary variables, and few would disagree that more detailed information is generally preferable. Decisions regarding the dichotomisation of variables will inevitably be subjective to a large degree, and may therefore be inappropriate or sub-optimal. Furthermore, the indices using categorical variables demonstrated considerably less clumping than the indices using binary variables, making it easier to generate quintiles of even size and improving differentiation between households. It could therefore be argued that PCA and MCA may be preferable over equal weights or inverse proportion approaches, despite the simple interpretation and ease of understanding for a wide audience of the latter two methods.

A further issue with PCA is its inappropriateness with discrete data, and in particular the spurious correlations introduced by using dummy indicators for categorical variables. MCA is one possible solution to this, which does not require specification of an ordinal structure to the categories. The indices generated by PCA and MCA demonstrated reasonable agreement, although the differential classification was non-negligible. When the ordering of categories can be ascertained, I would advocate the use of PCA with ordinal variables treated as continuous terms. When imposing such an ordinal structure is deemed not possible or not desirable, it would appear that using MCA or using PCA with dummy variables will result in reasonably similar final wealth indices. Given the level of similarity and the added complexity of applying MCA in standard statistical packages, it could be argued that using PCA with dummy variables is justifiable. PCA also has the advantage that continuous variables, such as area of land owned, can be included in the wealth index, whereas such variables cannot be incorporated into MCA unless they are categorised. In most cases, however, I would suggest that it is possible and indeed sensible to impose and ordinal structure on the data and use the ordinal variables as continuous terms in PCA.

Despite the fact that PCA is unfamiliar to many readers of epidemiological research papers and that it could be accused of obscuring the process of constructing a wealth index, there seems to be little reason to adopt any of the alternatives explored in this analysis, apart perhaps from MCA. The simpler methods resulted in indices with more clumping, and the inverse proportion method is unsuitable unless data collection has been preceded by substantial formative research. MCA, although being appropriate for nominal data, is more laborious to perform in Stata, no simpler to understand than PCA, and cannot be used with a mixture of discrete and continuous variables. My recommendation would be to either i) avoid the inclusion of nominal variables in a wealth index and use PCA with ordinal variables used as metric scores, or ii) if nominal variables are unavoidable and no continuous indicators are included in the wealth index, use MCA.

5.5.6 Further work

These analyses imply that the data used to construct a wealth index have a far stronger impact than the method used to weight the items. This issue could be explored further by investigating the effects of including different types of indicator in the wealth index; this will be explored in **Chapter 7**.

5.6 Chapter key messages

1. Although the first principal component of PCA often explains a low proportion of the total variance in the wealth index indicators, use of higher order components is not recommended
2. The spurious correlations introduced by including dummy variables for all categories of categorical variables have little impact on the final wealth index, since such an index had high agreement with one excluding the lowest frequency dummy variable
3. PCA methods appropriate for ordinal categorical data have only modest agreement with the inappropriate method of using dummy variables; use of ordinal variables as continuous terms in PCA is recommended

4. The way the indicators are coded has a far stronger impact on the final wealth index than the choice of method for weighting the indicators
5. Using ordinal variables with PCA, or using MCA with nominal variables, are the recommended approaches to wealth index construction

5.7 Next steps

This chapter has explored the construction of a wealth index using the indicators as used by the DHS, and constructing a single index for the whole sample. The next chapter will go on to explore area-effects of the wealth index. I will look at whether urban-rural patterns in wealth index scores are similar to those for consumption expenditure, or whether they differ in any systematic way. I will also explore the construction of separate wealth indices for each area. Wealth indices will continue to be constructed using PCA with dummy variables, despite the limitations explored in this chapter, since I am using the DHS wealth index as a starting block for exploration of the issues, and modifying just one aspect of this index in turn to evaluate the effects.

6. Area and the wealth index

This chapter addresses some of the issues relating to the use of the wealth index in different types of area. There is some concern that a wealth index may tend to overestimate the SEP of urban households, and underestimate that of rural households, given the urban bias of the indicators used to construct a wealth index. There is also some debate about whether a wealth index should be generated for a whole population, or whether PCA should be performed separately for urban and rural areas. This chapter is divided into three sections; the first explores how the features and characteristics of the wealth index differ in urban, peri-urban, and rural areas of Brazil and Malawi. The second section explores the effect of the indicators included in the wealth index on these features; some of those hypothesised to be introducing urban bias are removed from the wealth index, and the area-specific features of the wealth index are re-examined. The final section goes on to explore the question of whether a wealth index should be constructed for a whole population, or separately for urban, peri-urban, and rural areas.

6.1 Objectives & Hypotheses

The overall chapter objective is:

- To explore urban-rural differences in characteristics of the wealth index, and how these are affected by choices about wealth index construction.

The main objectives to be covered are:

1. To explore how characteristics of the wealth index differ across areas
2. The explore how area-specific characteristics of the wealth index are affected by the indicators included in the wealth index
3. To explore the construction of separate wealth indices for each area

Specific objectives will be detailed in each section.

My main hypotheses are:

1. Agreement of the wealth index will be lower in rural compared with urban areas
2. The distribution of the wealth index will be more clumped in rural areas of Malawi compared with urban areas
3. Including fewer urban-biased indicators or more rural-appropriate indicators in the wealth index will reduce the observed differences between the areas in terms of characteristics of the wealth index
4. Constructing separate wealth indices for each area will result in a less clumped distribution in rural areas

6.2 Background

The wide disparities between urban and rural life in low- and middle-income countries complicate the construction and use of wealth indices. There are many ways in which urban and rural living standards have different determinants, including differences in preferences, prices, and availability of goods, services, employment and educational opportunities. The determinants and manifestations of socio-economic hierarchies are likely to be very different in urban and rural areas.[289]

Rural households are consistently classified as lower SEP than urban households using a wealth index.[307] In analyses of DHS surveys, urban households dominate the higher wealth index quintiles and rural households the bottom quintiles in most settings.[56] This is broadly consistent with other measures of SEP, which all estimate that SEP levels are on average considerably lower in rural areas of low- and middle-income countries compared with urban areas. Despite the burden of low SEP being primarily in rural areas, there are often important disparities within as well as between urban or rural populations.[308] Thus it is important to have an index that can identify and distinguish the households in both urban and rural areas.

There is some concern that a wealth index is overestimating the SEP of urban households, and underestimating that of rural households. A wealth index in

Mozambique was shown to rank urban households higher than a consumption measure, whilst rural households were ranked considerably lower by the wealth index compared with the consumption measure.[64] Filmer and Scott also demonstrated that in 11 low-income countries, the difference in the proportion of households living in urban areas between extreme quintiles was consistently greater for the wealth index than for consumption expenditure.[286] The systematic review presented in **Chapter 2** demonstrated that the wealth index tends to be a poorer proxy for consumption expenditure in rural areas compared with urban areas. These findings, however, contrast with another study, which showed similar (albeit low) agreement between a wealth index and consumption measure in rural and urban areas.[289]

The indicators that are most useful for measuring SEP will differ in a given location and between urban and rural areas, but there may be some predictability in this; for instance in densely populated areas, ownership of land and dwellings may be good at differentiating households of different relative wealth.[295] The items included in a wealth index may have different meanings in urban and rural areas; for example urban slum dwellers may live in dwellings made from modern materials and therefore score highly in housing material questions but in some respects their living standards will be lower than rural residents, e.g. they often live in more crowded and insecure conditions. The commonly used indicators for a wealth index have a strong urban bias; urban households are far more likely to have access to the consumer durables, modern housing materials, and public services that result in high wealth index scores. This does not mean that these indicators are not useful markers of living standards; certainly high quality housing, access to safe water and sanitation are all important in themselves, and indeed have direct influences on health. They could, however, arguably be viewed as indicators of community-level infrastructure rather than household SEP. The differences between urban and rural households in these indicators may principally be an area effect, which would in many analyses be more helpful examined separately from household-level factors. Removal of these indicators from the wealth index, however, would result in an index comprised entirely or ownership of consumer durables, which could potentially be viewed as an undesirably narrow concept of SEP.

Several studies have shown that the items that are predictive of consumption are not consistent between regions or between urban and rural areas.[270, 284, 309] Despite this, wealth indices are frequently constructed using the same set of assets for both urban and rural areas, and similar sets across wildly different countries. Furthermore, the indicators are often assigned the same weights in urban and rural areas. This implies that they have the same meaning in terms of their relationship with SEP in all areas, which is not necessarily a reasonable assumption. In the literature review of papers citing Filmer and Pritchett's paper (**Section 1.8**), just one of the identified studies stated that they had performed PCA separately for urban and rural areas in order to give the indicators area-appropriate weights.[110] Sequential DHS surveys from the same countries did not show differentials in living standards between urban and rural residents to be decreasing, so this is an issue that does not appear to be losing importance as consumer durables and access to services become more widely available.[307]

This chapter will explore whether the features of a wealth index differ between types of area, and whether different approaches to constructing the wealth index affect this. The analyses in this chapter mainly use the Malawi IHS2 data, but some points are further explored in the Brazil DHS dataset for comparative purposes.

6.3 Decisions on area classification

To investigate area effects on the wealth index, I first need to decide how different areas will be defined. In order to do this, I here examine the distribution of the Malawi IHS2 sample between types of area, and look at the patterns of asset ownership and consumption expenditure across these areas.

Table 6.1 shows the proportion of households estimated to be living in each type of enumeration area. The vast majority of households (81.0%) are located in rural areas. 12.4% of households are located within the four major urban centres of Malawi: Lilongwe, Blantyre, Mzuzu, and the Municipality of Zomba. In addition, a total of 6.6% of households are in areas that could be considered peri-urban: large urban centres, bomas (district administrative headquarters), small urban centres, and gazetted townships.

Table 6.1: Types of enumeration area

Enumeration Area Type	Number of households	%
Rural	9100	81.0
Major urban	1440	12.4
Boma/Large urban centre	200	1.5
Small urban centre	520	5.0
Gazetted townships	20	0.19

6.3.1 Patterns of asset ownership across areas

Table 6.2 displays the proportion of households owning each indicator from the Malawi core wealth index across urban, peri-urban and rural areas. The majority of assets and high SEP categories of categorical variables are present with higher frequency in urban areas, with the main exceptions being ownership of agricultural land and bicycles. The only indicator where there is a non statistically-significant difference across the areas is motorbikes, for which ownership is uniformly low.

The prevalence of asset ownership in peri-urban areas most often lies between that in large urban centres and rural areas. Whether the peri-urban areas are more similar to the major urban centres or to rural areas varies somewhat across types of asset.

Table 6.2: Ownership of assets across the whole population and urban, peri-urban and rural households

Asset	*% households with the asset (standard error)*				*P value from F test of urban, periurban, and rural areas*
	Whole population	*Major urban centres*	*Peri-urban areas*	*Rural areas*	
Drinking water source					
Piped into dwelling	2.3 (0.48)	12.4 (3.3)	2.4 (0.99)	0.65 (0.26)	
Piped outside dwelling	3.0 (0.35)	15.1 (2.2)	6.8 (2.4)	0.74 (0.18)	
Communal standpipe	16.9 (1.1)	50.6 (4.2)	28.2 (5.8)	10.5 (1.1)	
Personal handpipe/well	3.1 (0.33)	4.2 (1.5)	4.6 (1.7)	2.8 (0.30)	
Communal handpipe/well	67.2 (1.2)	16.5 (3.6)	53.8 (6.1)	76.4 (1.3)	
River/spring/lake/reservoir/ Other	7.6 (0.65)	1.2 (0.35)	4.3 (1.7)	8.9 (0.78)	<0.001
Toilet facility					
Flush toilet	2.9 (0.55)	13.6 (3.7)	4.7 (1.6)	1.0 (0.31)	
VIP latrine	2.0 (0.30)	3.9 (0.76)	4.0 (1.3)	1.5 (0.34)	
Traditional latrine with roof	57.7 (0.95)	61.9 (3.7)	59.7 (4.0)	56.9 (1.1)	
Traditional latrine no roof	20.8 (0.73)	17.9 (2.3)	19.2 (3.3)	21.4 (0.82)	
None or other	16.6 (0.60)	2.7 (1.0)	12.4 (2.6)	19.2 (0.71)	<0.001
Cooking fuel					
Collected firewood	74.5 (1.0)	12.2 (2.9)	41.9 (6.3)	87.2 (8.9)	
Purchased firewood	14.6 (0.87)	23.5 (2.4)	46.6 (5.6)	10.5 (0.78)	
Paraffin/gas/charcoal	7.8 (0.49)	52.2 (3.2)	10.2 (3.5)	0.49 (0.13)	
Electricity	1.8 (0.37)	11.5 (2.8)	1.3 (0.59)	0.27 (0.098)	
Crop residue/sawdust/ Other	1.3 (0.24)	0.61 (0.30)	0.12 (0.12)	1.5 (0.30)	<0.001
Material of dwelling floor					
Sand	2.9 (0.35)	0.69 (0.41)	3.0 (1.3)	3.2 (0.44)	
Smoothed mud, or other	76.6 (0.88)	33.1 (3.3)	58.0 (4.8)	85.1 (0.80)	
Smoothed cement, wood or tiles	20.5 (0.82)	66.3 (3.3)	39.0 (4.6)	11.7 (0.70)	<0.001
Electricity in home	6.2 (0.56)	33.6 (3.7)	13.3 (2.8)	1.1 (0.25)	<0.001
TV / VCR	3.9 (0.42)	18.0 (2.9)	8.9 (1.8)	1.3 (0.16)	<0.001
Bike	36.3 (0.60)	19.0 (1.5)	41.6 (2.2)	38.7 (0.70)	<0.001
Motorbike/Scooter	0.38 (0.061)	0.59 (0.19)	0.71 (0.44)	0.31 (0.059)	0.17
Car	1.3 (0.26)	6.1 (1.9)	2.1 (0.80)	0.46 (0.086)	<0.001
Domestic servant	2.0 (0.21)	5.6 (1.3)	3.5 (0.92)	1.2 (0.13)	<0.001
Owns agricultural land	87.2 (0.58)	39.3 (2.8)	79.8 (3.2)	95.5 (0.47)	<0.001

6.3.2 Patterns in consumption expenditure across areas

Table 6.3 shows the mean per capita consumption expenditure across the whole population, and urban, peri-urban and rural areas. In general, consumption expenditure is higher in urban areas than rural areas, and the differences are pronounced and statistically significant. Overall, consumption expenditure in urban areas is approximately twice that in rural areas. The relative difference is greater in non-food expenditure (approximately three times higher in urban areas) compared with food expenditure (approximately two times higher in urban areas). When examining the differences in categories of expenditure, particularly striking differences are seen in expenditure on communication (approximately 30 times higher in urban areas), education (approximately seven times higher in urban areas), recreation (approximately seven times higher in urban areas), and transport (approximately six times higher in urban areas). In all categories, mean consumption expenditure in peri-urban areas is intermediate of that in major urban centres and rural areas. Whether the peri-urban areas are more similar to major urban centres or to rural areas varies between categories; peri-urban areas are more similar to rural areas in expenditure on food/beverages, furnishings, transport, and education, whereas they are more similar to major urban centres in expenditure on alcohol/tobacco, clothing/footwear, health, communications, recreation, and vendors/cafes. In overall total consumption expenditure, total food expenditure, and two of the sub-categories (housing/utilities, miscellaneous goods/services) peri-urban areas lie fairly centrally between major urban centres and rural areas.

Measurement error in consumption expenditure may have differed between the areas. The proportion of expenditure that relates to home-produced goods is higher in rural areas. Imputed values of home-produce tend to be less variable than the real data would have been.[31] This could reflect households having poorer recall of quantities of home-produced goods in comparison with purchased goods. Measurement error of consumption expenditure could therefore be hypothesised to be greater in rural areas.

Table 6.3: Patterns of per capita consumption expenditure across the whole population, urban, peri-urban and rural areas

	Mean (SE) in whole population	*Mean (SE) in major urban areas*	*Mean (SE) in peri-urban areas*	*Mean (SE) in rural areas*	*p value (Wald test from regression analyses)*
Total per capita consumption expenditure	25190.0 (652.6)	48728.6 (4382.4)	30575.5 (1907.5)	20962.5 (343.9)	<0.001
Food expenditure per capita	14315.0 (272.0)	23263.4 (1421.5)	17409.8 (1098.1)	12622.9 (222.6)	<0.001
Non-food expenditure per capita	10875.0 (432.2)	25465.2 (3102.1)	13165.7 (959.9)	8339.6 (169.9)	<0.001
Categories of consumption expenditure:					
Food/beverages	14030.9 (263.1)	22546.4 (1368.0)	16700.0 (1022.8)	12443.0 (219.4)	<0.001
Alcohol/tobacco	647.2 (32.9)	1104.0 (183.2)	815.0 (106.3)	560.0 (26.7)	0.0012
Clothing/footwear	1026.0 (33.5)	2083.3 (160.9)	1542.2 (202.5)	813.9 (27.5)	<0.001
Housing/utilities	5302.9 (130.7)	9519.6 (831.2)	5908.0 (376.3)	4574.7 (85.8)	<0.001
Furnishings	885.7 (48.8)	2248.3 (349.6)	1085.8 (114.8)	650.0 (20.1)	<0.001
Health	297.0 (12.2)	480.6 (62.0)	416.3 (65.2)	257.8 (10.1)	0.0002
Transport	1305.7 (127.2)	4885.7 (937.1)	1555.3 (283.2)	709.0 (39.8)	<0.001
Communications	204.7 (38.5)	1332.1 (293.1)	208.8 (55.4)	22.9 (5.6)	<0.001
Recreation	208.6 (21.1)	883.5 (155.1)	313.4 (44.3)	91.5 (6.6)	<0.001
Education	292.7 (41.0)	1143.7 (304.3)	372.8 (55.2)	149.1 (12.9)	<0.001
Vendors/cafes	284.1 (20.7)	717.0 (128.9)	709.4 (111.6)	179.9 (9.6)	<0.001
Miscellaneous goods/services	704.5 (28.4)	1784.4 (198.7)	948.1 (77.0)	510.8 (12.7)	<0.001

6.3.3 Conclusions on area classifications

Defining urban and rural populations is challenging, and there is no single definition that would be appropriate for all contexts.[310] In the Malawi IHS2, primary sampling units were census enumeration areas (EAs), based on administrative boundaries. EAs were classified as major urban centres (Lilongwe, Blantyre, Mzuzu, and the Municipality of Zomba), Bomas/large urban centres, small urban centres, gazetted townships, or rural. In the main report on the IHS2 produced by the National Statistical Office of Malawi, all areas apart from the four major urban centres are classified as rural. However, I have shown above that peri-urban areas are quite distinct from both major urban centres and rural areas in terms of both asset ownership and consumption. I therefore feel it is appropriate to maintain three separate categories of urban, peri-urban and rural in future analyses of the Malawi IHS2 data. The Brazil DHS data also classifies households as urban, peri-urban and rural, and so for consistency this categorisation will also be used in analysis of the Brazil dataset in preference over the dichotomised urban-rural classification.

6.4 Features of the wealth index in each area

6.4.1 Background

The items commonly included in wealth indices have an urban-bias, i.e. they are more likely to be owned in urban areas. This is confirmed by **Table 6.2**, which showed strong area patterns for almost all indicators. Higher levels of wealth are certainly one reason for the area patterns in asset ownership, but other potential reasons include availability of public services, availability of durable goods to purchase, preferences, and cultural factors.

The extent to which the distribution, patterns across quintiles, and agreement with consumption differ across urban, peri-urban and rural areas in the Malawi IHS2 will be investigated in this section. For comparative purposes, the distribution and patterns across quintiles will also be explored for the Brazil DHS.

6.4.2 Objectives

1. Examine features of the wealth index in urban, peri-urban and rural areas
2. Compare the agreement of the wealth index with consumption expenditure across urban, peri-urban and rural areas
3. Compare the relative positions of households in the wealth index hierarchy and in the consumption expenditure hierarchy in each area

6.4.3 Hypotheses

1. The wealth index distribution will exhibit more clumping and truncation in rural areas compared with peri-urban and urban areas, since many rural households will have none or few of the core assets
2. The mean wealth index scores will be highest in urban areas, intermediate n peri-urban areas, and lowest in rural areas
3. The wealth index will be a better proxy for consumption expenditure in urban areas, consistent with the systematic review in Chapter 2, and the patterns of consumption expenditure across areas shown in **Section 6.2**
4. On average, an urban households rank in the wealth index hierarchy will be higher than its rank in the consumption expenditure hierarchy, and vice versa for rural households due to the urban bias of the indicators

6.4.4 Methods

For both the Malawi IHS2 and Brazil DHS datasets, wealth indices using the core set of assets (**Section 4.2** and **Section 2.2.3**) were constructed for the whole population using PCA to assign weights to the indicators. The distribution of the indices, the weights assigned to the indicators, the urban/peri-urban/rural patterns of classification into quintiles of the wealth index, and the mean score across quintiles in each area were explored. For the Malawi dataset, agreement with consumption was assessed using classification into quintiles. The tendency of the wealth index to rank households as higher or lower in the SEP hierarchy than consumption expenditure was assessed in each area.

6.4.5 Results

6.4.5.1 Mean wealth index scores in urban, peri-urban and rural areas

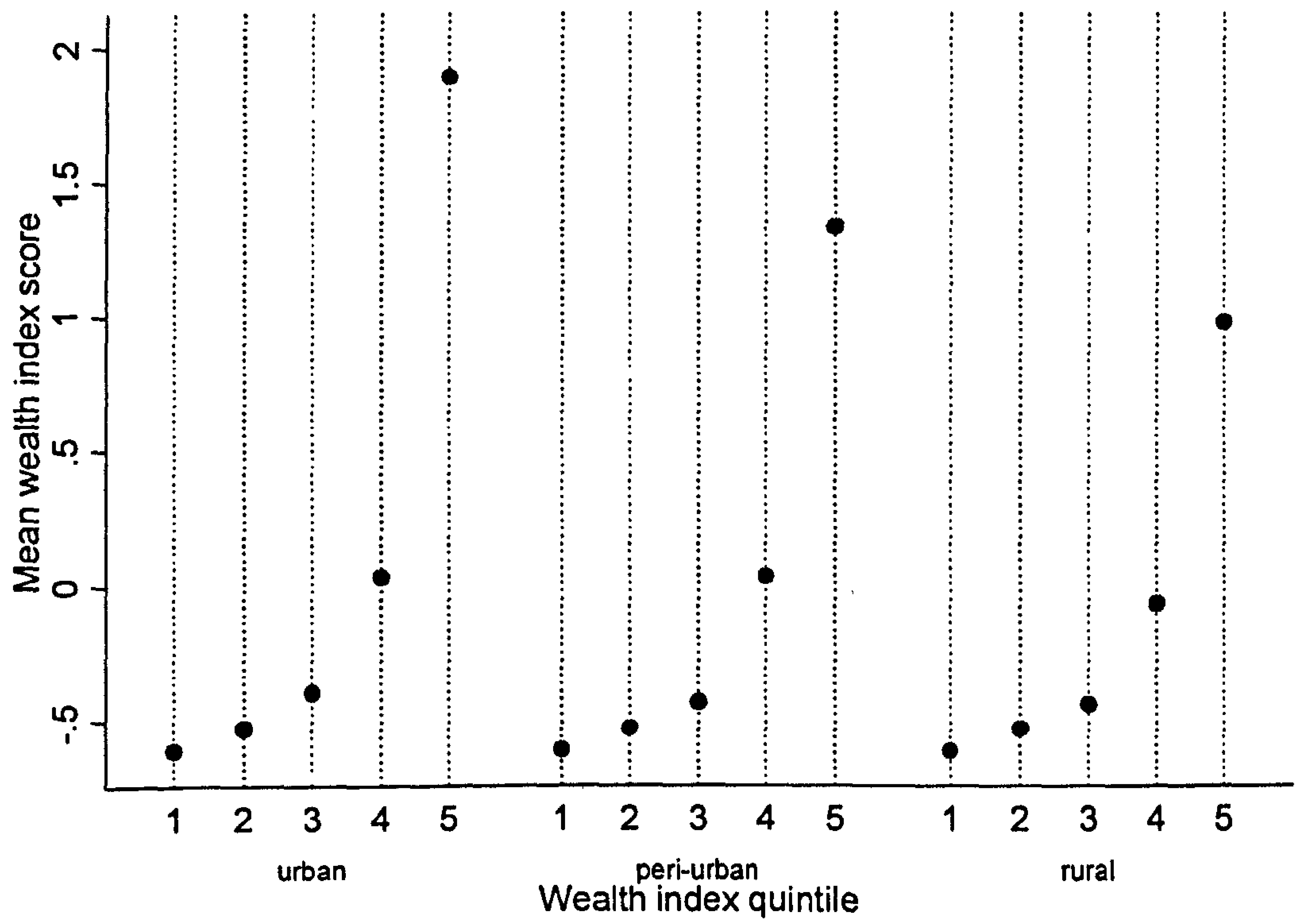
In both Malawi and Brazil, the mean wealth index score is highest in urban areas and lowest in rural areas, with peri-urban areas falling between urban and rural (**Table 6.4**). It is also interesting to note that the mean wealth index scores are not evenly distributed across quintiles of the wealth index. This is particularly marked in Malawi, where there is a fairly steady increase in mean score across the bottom three quintiles, but the mean score jumps between the third and fourth quintiles, and the gap between the fourth and top quintiles is even more pronounced (**Figure 6.1A**). The mean score in the top quintile, and the gap between the mean scores of the fourth and top quintiles are both considerably greater in urban areas compared with peri-urban and rural areas. In Brazil, the mean score is more evenly spaced across quintiles, although some deviations from linearity are present. The gap between the bottom quintile and the second quintile tends to be disproportionately large, particularly for rural areas (**Figure 6.1B**).

Table 6.4: Mean wealth index score for the whole population index using core assets overall and within urban, peri-urban and rural areas

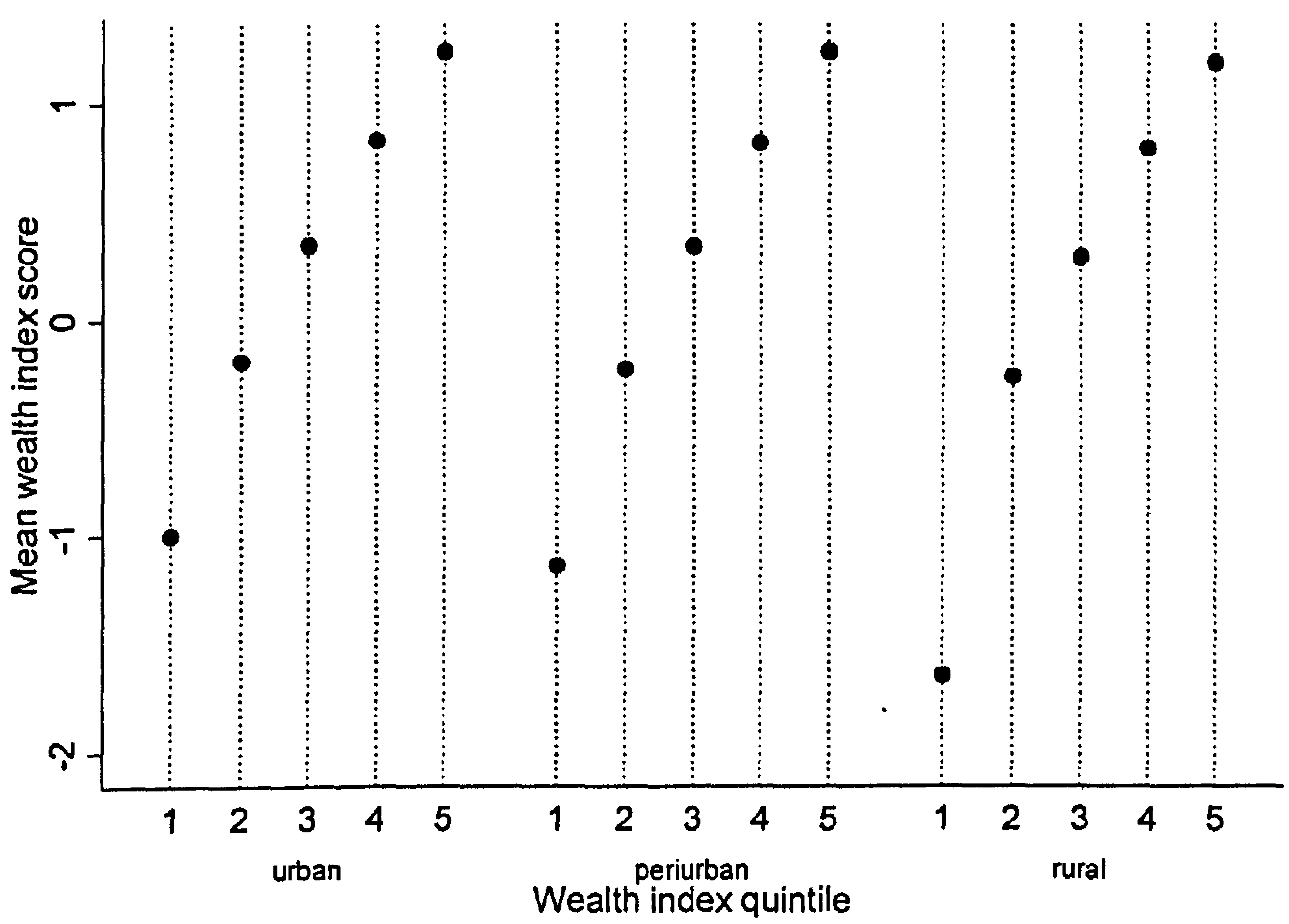
	Mean score (SE)	
	Malawi	**Brazil**
Whole population	-0.0153 (0.0254)	0.000 (0.00872)
Urban areas	1.544 (0.148)	0.481 (0.0103)
Peri-urban areas	0.451 (0.118)	0.104 (0.0110)
Rural areas	-0.304 (0.0157)	-1.035 (0.0193)

Figure 6.1: Mean wealth index scores across quintiles of the wealth index in each area

A: Malawi



B: Brazil

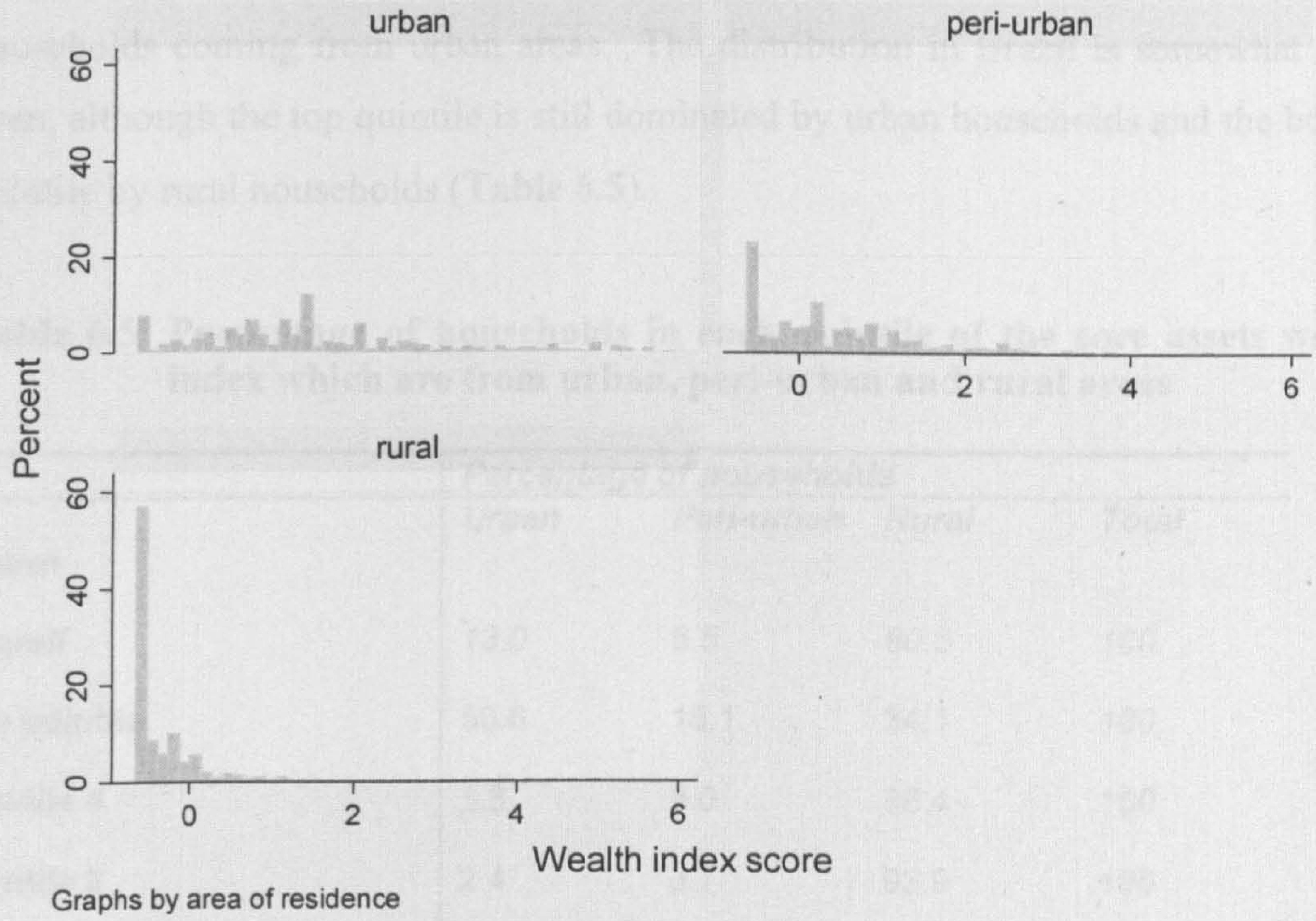


6.4.5.2 Distribution of the wealth index in urban, peri-urban and rural areas

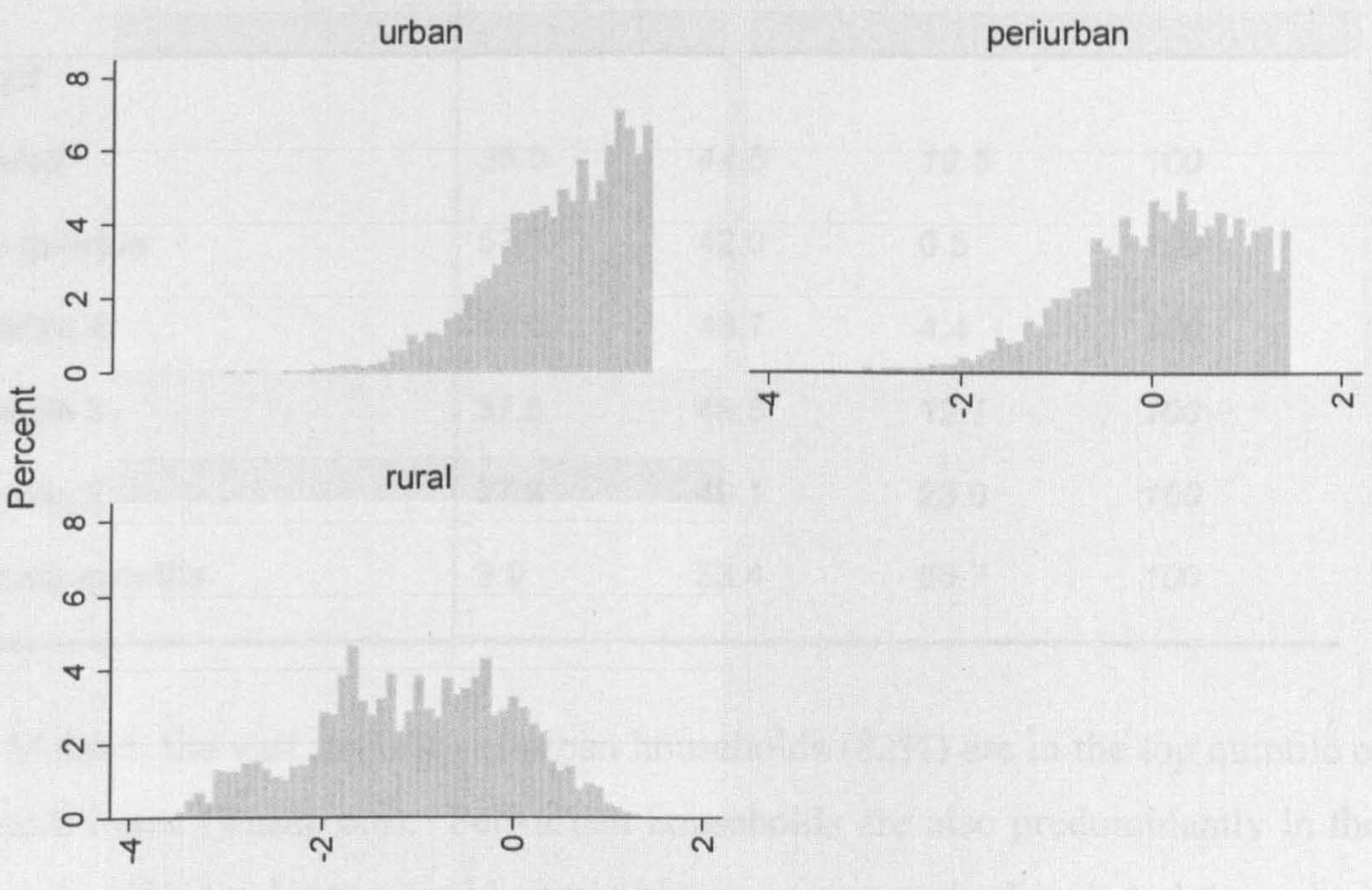
The area patterns of wealth index distribution differ markedly between Malawi and Brazil. In Malawi, there is considerable clumping at lower values of the index within rural areas, and to a lesser extent in peri-urban areas (**Figure 6.2A**). Clumping is less of an issue in Brazil, but truncation is present in both urban and peri-urban areas (**Figure 6.2B**). The difference between the distributions in Malawi and Brazil is interesting; despite truncation in urban and peri-urban areas, the distribution in Brazil generally tends to approximate a normal distribution far more closely than the distribution in Malawi. This could imply that the wealth index is better able to differentiate between households in Brazil than in Malawi. It is also noteworthy that the distributional problems are concentrated in urban areas of Brazil, but in rural areas of Malawi.

Figure 6.2: Distribution of the whole population wealth index using core assets within urban, peri-urban and rural areas

A: Malawi



B: Brazil



6.4.5.3 Urban/peri-urban/rural composition of the index

The bottom three quintiles of the whole population index in Malawi are almost exclusively rural (**Table 6.5**). The top quintile is predominantly urban, with 51% of households coming from urban areas. The distribution in Brazil is somewhat more even, although the top quintile is still dominated by urban households and the bottom quintile by rural households (**Table 6.5**).

Table 6.5: Percentage of households in each quintile of the core assets wealth index which are from urban, peri-urban and rural areas

	Percentage of households			
	Urban	*Peri-urban*	*Rural*	*Total*
Malawi				
Overall	*13.0*	*6.5*	*80.5*	*100*
Top quintile	50.8	15.1	34.1	*100*
Quintile 4	5.6	8.0	86.4	*100*
Quintile 3	2.4	3.7	93.9	*100*
Quintile 2	1.3	2.9	95.8	*100*
Bottom quintile	2.3	4.1	93.6	*100*
Brazil				
Overall	*36.0*	*44.5*	*19.5*	*100*
Top quintile	57.5	42.0	0.5	*100*
Quintile 4	47.0	48.7	4.4	*100*
Quintile 3	37.5	49.8	12.7	*100*
Quintile 2	27.9	49.1	23.0	*100*
Bottom quintile	9.9	33.4	56.7	*100*

In Malawi, the vast majority of urban households (82%) are in the top quintile of the wealth index (**Table 6.6**). Peri-urban households are also predominantly in the top quintile (45%), whereas rural households are more evenly distributed throughout the quintiles. This table also demonstrates that the clumping in the distribution of the wealth index in Malawi makes the identification of clear quintiles difficult; 28% of households are in quintile 2 while just 12% are in quintile 3.

In Brazil, the differences in quintile classification of urban, peri-urban, and rural households are less stark, but exist nonetheless. There is still a tendency for urban households to be in the top quintiles of the wealth index, and a strong tendency for rural households to be in the bottom quintile. Peri-urban households, on the other hand, are reasonably evenly distributed across the wealth index quintiles (**Table 6.6**).

Table 6.6: Percentage of households in urban, peri-urban and rural areas in each quintile of the core assets wealth index

	Percentage of households			
	Urban	*Peri-urban*	*Rural*	*Total*
Malawi				
Top quintile	82.1	45.1	8.4	*20.0*
Quintile 4	8.9	23.7	21.3	*19.9*
Quintile 3	2.3	6.5	13.7	*11.8*
Quintile 2	2.9	12.2	33.2	*28.0*
Bottom quintile	3.8	12.5	13.5	*20.3*
Total	*100*	*100*	*100*	*100*
Brazil				
Top quintile	31.8	18.7	0.5	*19.9*
Quintile 4	26.3	21.9	4.5	*20.1*
Quintile 3	20.9	22.3	13.0	*20.0*
Quintile 2	15.5	22.0	23.7	*20.0*
Bottom quintile	5.5	15.0	58.3	*20.0*
Total	*100*	*100*	*100*	*100*

6.4.5.4 Agreement with consumption expenditure

Agreement between classification into quintiles of the wealth indices and per capita consumption expenditure was low in all cases, but differed markedly across areas of Malawi (**Table 6.7**); it was highest in urban areas with just over half of households being classified into the same quintile, intermediate in peri-urban areas with approximately a third of households in the same quintile, and lowest in rural areas, with approximately a quarter of households in the same quintile. Kappa statistics and correlation coefficients also reflect this pattern. The extent of gross misclassification is also greatest in rural areas, intermediate in peri-urban areas and lowest in urban areas.

Table 6.8 shows the transition matrices for classification across quintiles of per capita consumption expenditure and the wealth indices; this shows some striking differences in the patterns across areas. Agreement for households in the bottom quintile of consumption expenditures is universally low, but is lowest in urban areas. Agreement for households in the top quintile of expenditures, however, was 94.8% in urban areas, compared with just 18.7% in rural areas. Agreement is generally lowest for households in the middle quintiles; in particular agreement drops to just 1.1% for urban households in the middle quintile of expenditures. In urban and peri-urban areas, the wealth index performs best as a proxy for consumption expenditure with regards to identifying the better-off households. In rural areas, however, the strongest agreement in classification is in the poorest two quintiles. This finding reinforces the concern that, in Malawi at least, a wealth index is unable to identify and differentiate between the urban poor and the rural wealthy.

Whether a wealth index tended to rank households higher or lower than consumption expenditure differed between types of area (**Table 6.9**). In urban areas, the wealth index tended to rank households higher than consumption expenditure, whereas in peri-urban areas a roughly equal proportion of households were ranked higher and lower by the wealth index compared with consumption expenditure, and in rural areas almost half of households were ranked lower by the wealth index than by consumption expenditure. This supports concerns that, in Malawi at least, a wealth index tends to overestimate the SEP of urban households and underestimate that of rural households.

Table 6.7: Agreement between quintiles of wealth indices using the core assets and per capita consumption expenditure

	% Households moving between quintiles of wealth index and per capita consumption expenditure							
Index	*Same quintile*	*Move 1 quintile*	*Move 2 quintiles*	*Move 3 quintiles*	*Move 4 quintiles*	*Kappa (SE)*	*Correlation*	*Correlation of logged measures*
Whole population (n=11243)	28.9	33.5	20.4	13.6	3.6	*0.11 (0.005)*	*0.54*	*0.46*
Urban areas (n=1434)	54.7	24.0	12.7	6.6	2.1	*0.16 (0.01)*	*0.57*	*0.53*
Peri-urban areas (n=739)	37.5	35.4	14.7	10.7	1.8	*0.13 (0.02)*	*0.42*	*0.32*
Rural areas (n=9070)	24.1	34.9	22.1	15.0	4.0	*0.05 (0.005)*	*0.35*	*0.31*

Table 6.8: Transition matrices of classification between quintiles of per capita consumption expenditure and the wealth indices using core assets

A: Whole population

Quintiles of per capita consumption expenditure		*Quintiles of the wealth index using core assets* Q1 (Lowest)	Q2	Q3	Q4	Q5 (Highest)	*Total*
	Q1 (Lowest)	**29.7**	32.6	16.9	17.0	3.9	100
	Q2	26.4	**32.9**	13.7	19.2	7.8	100
	Q3	22.5	31.6	**13.9**	20.2	11.9	100
	Q4	21.2	26.8	12.6	**21.4**	18.1	100
	Q5 (Highest)	11.3	19.2	7.8	18.7	**43.0**	100

B: Urban areas

Quintiles of per capita consumption expenditure		*Quintiles of the wealth index using core assets* Q1 (Lowest)	Q2	Q3	Q4	Q5 (Highest)	*Total*
	Q1 (Lowest)	**19.3**	8.2	10.1	22.1	40.3	100
	Q2	11.8	**7.0**	11.5	14.6	55.1	100
	Q3	6.6	7.8	**1.1**	15.3	69.2	100
	Q4	5.4	3.5	3.1	**10.5**	77.5	100
	Q5 (Highest)	0.53	0.16	0.47	4.1	**94.8**	100

C: Peri-urban areas

Quintiles of per capita consumption expenditure		Quintiles of the wealth index using core assets Q1 (Lowest)	Q2	Q3	Q4	Q5 (Highest)	Total
	Q1 (Lowest)	**27.7**	29.3	13.6	21.8	7.6	100
	Q2	22.4	**13.7**	10.6	27.7	25.7	100
	Q3	20.9	14.9	**8.4**	29.6	26.3	100
	Q4	9.8	9.6	5.7	**29.2**	45.8	100
	Q5 (Highest)	2.5	7.4	2.9	26.1	**61.1**	100

D: Rural areas

Quintiles of per capita consumption expenditure		Quintiles of the wealth index using core assets					Total
		Q1 (Lowest)	Q2	Q3	Q4	Q5 (Highest)	
	Q1 (Lowest)	**30.2**	33.8	17.3	16.5	2.2	100
	Q2	27.6	**35.7**	14.1	19.0	3.7	100
	Q3	24.3	34.9	**15.5**	20.2	5.2	100
	Q4	24.5	31.7	14.6	**22.4**	6.38	100
	Q5 (Highest)	17.1	29.1	11.6	23.5	**18.7**	100

Table 6.9: Increased, decreased or unchanged ranking of households between per capita consumption expenditure and wealth indices using the core assets

Index	*Lower quintile by wealth index*	*Same quintile*	*Higher quintile by wealth index*
Whole population (n=11243)	42.6	28.9	28.4
Urban areas (n=1434)	7.6	55.0	37.4
Peri-urban areas (n=739)	28.8	37.4	33.8
Rural areas (n=9070)	49.4	24.1	26.5

6.4.6 Discussion

There are strong differences between features of the wealth index across urban, peri-urban and rural areas in both Malawi and Brazil. In both countries, urban households are generally assigned higher scores in the wealth index than their rural counterparts. In Malawi, the wealth index distribution suffers from severe clumping at low values in rural areas. In contrast, the wealth index in Brazil approximates a normal distribution in rural areas, but suffers from truncation in urban and peri-urban areas. These analyses have confirmed that in Malawi, the wealth index has stronger agreement with consumption expenditure in urban areas compared with peri-urban and rural areas, and that the wealth index tends to rank rural households as lower in the socio-economic hierarchy than consumption expenditure, and vice versa for urban households. The differential measurement error in consumption expenditure across areas may have affected the comparisons of the wealth index with consumption expenditure. Measurement of consumption expenditure may have been biased downwards in rural areas to a greater degree than in urban areas, due to under-reporting of home-produced goods. If this is the case, this may affect the results of these analyses. For instance, rural households tend to be placed in a lower quintile of the wealth index than of consumption expenditure; if consumption expenditure of rural households is underestimated, the true strength of this differential ranking may be even greater.

These results support the concern that, in Malawi at least, a wealth index is a weak tool for identifying the urban poor and the rural wealthy. The striking differences in the patterns in Malawi and Brazil, however, suggest that this issue may be restricted to Malawi or countries with a similar level of economic development to Malawi. The distributions of the wealth index in Brazil suggest that in this context, it may be the urban wealthy that the wealth index is struggling to distinguish.

The analyses of the Brazilian data do not take regional differences into account; Brazil is a large heterogeneous country with considerable variation in living standards. In particular, the urban areas of the South are far richer than the urban areas of the North. This is likely to have affected the findings presented here. For instance, the difference in mean scores between urban and rural areas may have been lower in the North than in the South.

6.5 *Effect of indicators on features of the wealth index*

6.5.1 Background

The concern that a wealth index may overestimate the SEP of urban households and underestimate that of rural households has arisen out of a concern about the urban-bias of the indicators used to construct a wealth index. This section will explore whether the features of the wealth index in each area, as described in the above section, are altered by the exclusion of some of the indicators hypothesised to have the greatest urban bias.

It could be argued that much of the observed difference in wealth index scores between urban and rural households relates largely to the availability of electricity. In addition to electricity supply itself, many of the other items frequently included in wealth indices require an electricity connection, for instance television, telephone, and refrigerator ownership. Electricity connections are likely to be far more widely available in urban areas and are provided at the community level; rural households may lack electricity not simply because they cannot afford it but because it is not available in their area. It may be the case, therefore, that much of the observed difference in wealth between urban and rural households, and the increasing rank of urban households and decreasing rank of rural households by wealth indices compared with consumption expenditure is due to inclusion of electricity supply in the wealth index. Exclusion of electricity from the wealth index may therefore reduce the observed difference in wealth between urban and rural households. It may also assist with differentiating between poor and less poor in urban areas, such that lower quintiles of the wealth index contain a higher proportion of urban households. Houweling *et al.* reported that observed inequalities in child mortality changed when electricity was excluded from a wealth index, although the magnitude and direction of change could not be predicted.[311]

A larger still degree of the differences in wealth index scores between urban and rural areas may be explained by access to publicly-provided services such as electricity supply, sanitation facilities, and drinking water supply. Such public services are determined primarily at the community level and are far less likely to be present in rural areas. If there is no piped water supply to a whole community, a household living in that community cannot have access to piped water no matter what their SEP. Inclusion of public services in a wealth index will therefore result in an index with a low degree of separation between households within a community, particularly in rural areas. It is possible, therefore, that exclusion of public services from the wealth index may decrease the observed difference between wealth in urban and rural areas, and alter the differential re-ranking of urban and rural households by consumption expenditure and the wealth index. Houweling's paper also constructed wealth indices excluding public services (water and sanitation facilities) and again noted effects on observed inequalities in child mortality, but the direction and magnitude of change did not follow the same pattern across countries.[311]

A further issue in area effects on the construction of wealth indices is that of housing-related items. In rural areas of developing countries, it is very difficult to place a monetary value on housing. Housing markets are limited or even non-existent. Furthermore, dwellings are often constructed rather than purchased, goods used to construct dwellings may have been gathered rather than purchased, and the labour may have been all or primarily family labour. It is therefore questionable whether it is appropriate to include housing-related items in an index intending to proxy economic position in rural areas[32], or at least whether housing indicators should be given the same weight in urban and rural areas.

6.5.2 Objectives

1. Identify the degree to which urban-rural patterns of wealth index features are driven by a few key urban-biased wealth index indicators

6.5.3 Hypotheses

Excluding urban-biased indicators from the wealth index will:

1. increase the proportion of rural households in higher quintiles of the wealth index
2. reduce the difference in mean scores of the wealth index between urban and rural areas
3. result in fewer rural households being ranked lower by the wealth index than by consumption expenditure
4. improve the agreement of the wealth index with consumption expenditure in rural areas

6.5.4 Methods

The wealth index using the core assets was constructed for the Malawi IHS2 dataset, excluding: i) electricity, ii) electricity and consumer durables dependent on it (TV/VCR), iii) community-level services (electricity, water supply, sanitation facilities), iv) housing related items (material of dwelling floor, ownership of agricultural land).

For each construction of the wealth index, and for each area, the distribution was assessed by histograms, the mean score was calculated, and agreement and relative ranking with quintiles of consumption expenditure was calculated. These were compared with the index using all core assets.

For each construction of the wealth index, the inequality in child stunting was calculated, but since this is not crucial to the objectives of this work it is presented in **Appendix B**.

6.5.5 Results

6.5.5.1 Excluding electricity and consumer durables dependent on electricity

Removing electricity from the wealth index results in a slightly lower proportion of the variance being explained by the first principal component; removing consumer durables dependent on electricity leads to a further decrease **(Table 6.10)**. The magnitude of some other indicators is increased in the indices excluding electricity and items dependent on it, but changes are not substantial.

Figure 6.3 shows the distribution of the indices across types of area. There is very little difference between these indices and the index including electricity and items dependent on it **(Figure 6.4)**.

There is no evidence that excluding electricity or excluding electricity and consumer durables dependent on electricity reduces the observed wealth gap between urban and rural areas (**Table 6.11**); the difference between mean scores between urban and rural areas increases by two percent when electricity is excluded from the index, and by seven percent when electricity and items dependent on it are excluded.

It is not the case that excluding electricity and consumer durables dependent on it has increased the proportion of rural households in higher quintiles of the wealth index. In fact, the distribution of households within quintiles remains remarkably similar between the core index and the two indices excluding electricity and excluding electricity and consumer durables dependent on it (**Table 6.12**).

Excluding electricity or excluding electricity and consumer durables dependent on it has very little effect on the overall agreement of classification into quintiles of the wealth index and consumption expenditure (**Table 6.13**). When comparing the proportional difference in agreement with consumption expenditure between areas, there is very little difference between the three indices.

There is no evidence that excluding electricity or electricity and consumer durables dependent on it affects the re-ranking of households with respect to consumption expenditure (**Table 6.14**).

6.5.5.2 Excluding community-level variables

Exclusion of public services from the wealth index resulted in an increase in the proportion of variance explained by the first principal component (**Table 6.10**). The weights of the other indicators are increased slightly in magnitude.

The wealth index displays far more clumping at lower values than the index which included public services (**Figure 6.5**). The clumping is particularly severe in rural areas, but is also fairly extensive in peri-urban areas. This goes against my initial hypothesis that the exclusion of public services may improve the ability of the wealth index to distinguish between rural households.

As with excluding electricity supply from the wealth index, there is no evidence that exclusion of all public services reduces the observed wealth difference in mean wealth index scores between urban and rural areas (**Table 6.11**); the difference is two percent higher when community-level variables are excluded from the wealth index. There is, however, an indication that the wealth index excluding public services results in a reduced difference in the mean wealth index score between urban and peri-urban households (difference in mean scores is eight percent less when community-level variables are excluded from the wealth index), suggesting that a substantial part of the difference in wealth index scores between these areas may be attributable to access to public services.

It was not the case that excluding community-level public services from the wealth index resulted in an increased proportion of households in the upper quintiles being from rural areas (**Table 6.12**). In fact, the proportion of households in the top quintile coming from rural areas is reduced from 34% in the main index to 28% in the index excluding public services.

There is little effect on agreement of the wealth index with consumption expenditure when public services are excluded from the index (**Table 6.13**).

Within urban areas, a very slightly lower proportion of households are ranked higher by the wealth index excluding public services than by consumption expenditure, compared with the core wealth index (**Table 6.14**). The difference in these proportions (37.4% in the core wealth index and 35.8% in the index excluding public services) is very small. The proportion of rural households ranked lower by a wealth index than by consumption expenditure is actually slightly higher in the wealth index excluding public services, contrary to my original hypothesis.

6.5.5.3 Excluding housing-related items from the wealth index

The proportion of the total variance explained by the first principal component is slightly less in the index excluding housing-related items compared with the index using all core assets (**Table 6.10**). The magnitude of weights for most of the remaining indicators is increased slightly.

As hypothesised, excluding housing-related items from the wealth index reduced the observed difference in wealth between urban and rural areas, the observed difference was 15.2% less in the index excluding housing-related items compared with the core index (**Table 6.11**).

Excluding housing-related items from the wealth index did not have a substantial effect on the distribution of the index; clumping remains severe in rural areas and is not dramatically altered in any area (**Figure 6.6**). There is also little change in the urban, peri-urban and rural composition of the quintiles of wealth index; if anything there is a slightly lower proportion of rural households in the top quintile when housing items are excluded from the wealth index (**Table 6.12**).

Excluding housing-related items from the wealth index had remarkably little impact on the observed agreement between the wealth index and per capita consumption expenditure (**Table 6.13**). There was also very little difference in the proportion of households ranked higher or lower by the wealth index compared with consumption expenditure in any area (**Table 6.14**).

Table 6.10: Weights assigned to index items and percentage of the total variance explained by the first principal component of the wealth indices using the core set of assets, excluding electricity and excluding electricity and items dependent on it

Asset	*Wealth index using core assets*	*Wealth index excluding electricity*	*Wealth index excluding electricity and dependent items*	*Wealth index excluding community -level services*	*Wealth index excluding housing items*
% variance explained by first principal component	*18.9*	*17.5*	*17.0*	*23.2*	*17.8*
Has electricity	0.3426	-	-	-	0.3983
Has radio	0.0194	0.0283	0.0335	0.0397	0.0056
Has television/VCR	0.2835	0.2835	-	0.3063	0.3498
Has bicycle	0.0026	0.0059	0.0012	0.0130	-0.0005
Has motorbike/scooter	0.0432	0.0481	0.0447	0.0651	0.0500
Has car	0.1887	0.1937	0.1776	0.2072	0.2536
Has domestic servant	0.1425	0.1484	0.1407	0.1701	0.1810
Owns agricultural land	-0.2279	-0.2507	-0.2757	-0.3042	-
Drinking water source					
Piped into dwelling	0.2762	0.2763	0.2608	-	0.3692
Piped outside dwelling	0.1630	0.1654	0.1742		0.1588
Communal standpipe	0.1250	0.1536	0.1831		0.0932
Personal handpipe/well	0.0154	0.0214	0.0253		0.0145
Communal handpipe/well	-0.2269	-0.2510	-0.2735		-0.2358
River/spring/lake/reservoir/ Other	-0.0433	-0.0461	-0.0476		-0.0304
Toilet facility					
Flush toilet	0.2760	0.2767	0.2651	-	0.3622
VIP latrine	0.0893	0.0992	0.1080		0.0753
Traditional latrine with roof	0.0014	0.0106	0.0214		-0.0365
Traditional latrine no roof	-0.0611	-0.0650	-0.0676		-0.0564
None or other	-0.0923	-0.1048	-0.1144		-0.0800
Material of dwelling floor					
Sand	-0.0078	-0.0049	-0.0021	0.0132	-
Smoothed mud/other	-0.3116	-0.3414	-0.3626	-0.4281	
Smooth cement/wood/tiles	0.3313	0.3614	0.3825	0.4449	
Cooking fuel					
Collected firewood	-0.3047	-0.3372	-0.3639	-0.4162	-0.2990
Purchased firewood	0.1251	0.1512	0.1705	0.2122	0.1110
Paraffin/gas/charcoal	0.2194	0.2371	0.2618	0.2862	0.1880
Electricity	0.2452	0.2438	0.2279	0.2288	0.3281
Crop residue/sawdust/ other	0.0042	0.0077	0.0111	0.0164	0.0058

Table 6.11: Mean scores across quintiles of the wealth indices excluding electricity and excluding electricity and items dependent on it

	Mean score (SE)				
	Core wealth index	Wealth index excluding electricity	Wealth index excluding electricity and items dependent on it	Wealth index excluding community-level factors	Wealth index excluding housing-related items
Whole population	-0.0153 (0.0254)	-0.0134 (0.0252)	-0.0263 (0.0255)	-0.00910 (0.0227)	-0.0233 (0.0272)
Urban areas	1.544 (0.148)	1.580 (0.139)	1.400 (0.136)	1.584 (0.109)	1.302 (0.179)
Peri-urban areas	0.451 (0.118)	0.484 (0.121)	0.394 (0.117)	0.561 (0.132)	0.332 (0.101)
Rural areas	-0.304 (0.0157)	-0.310 (0.0168)	-0.290 (0.188)	-0.312 (0.0155)	-0.266 (0.0138)

Figure 6.3: Distribution of wealth index excluding electricity

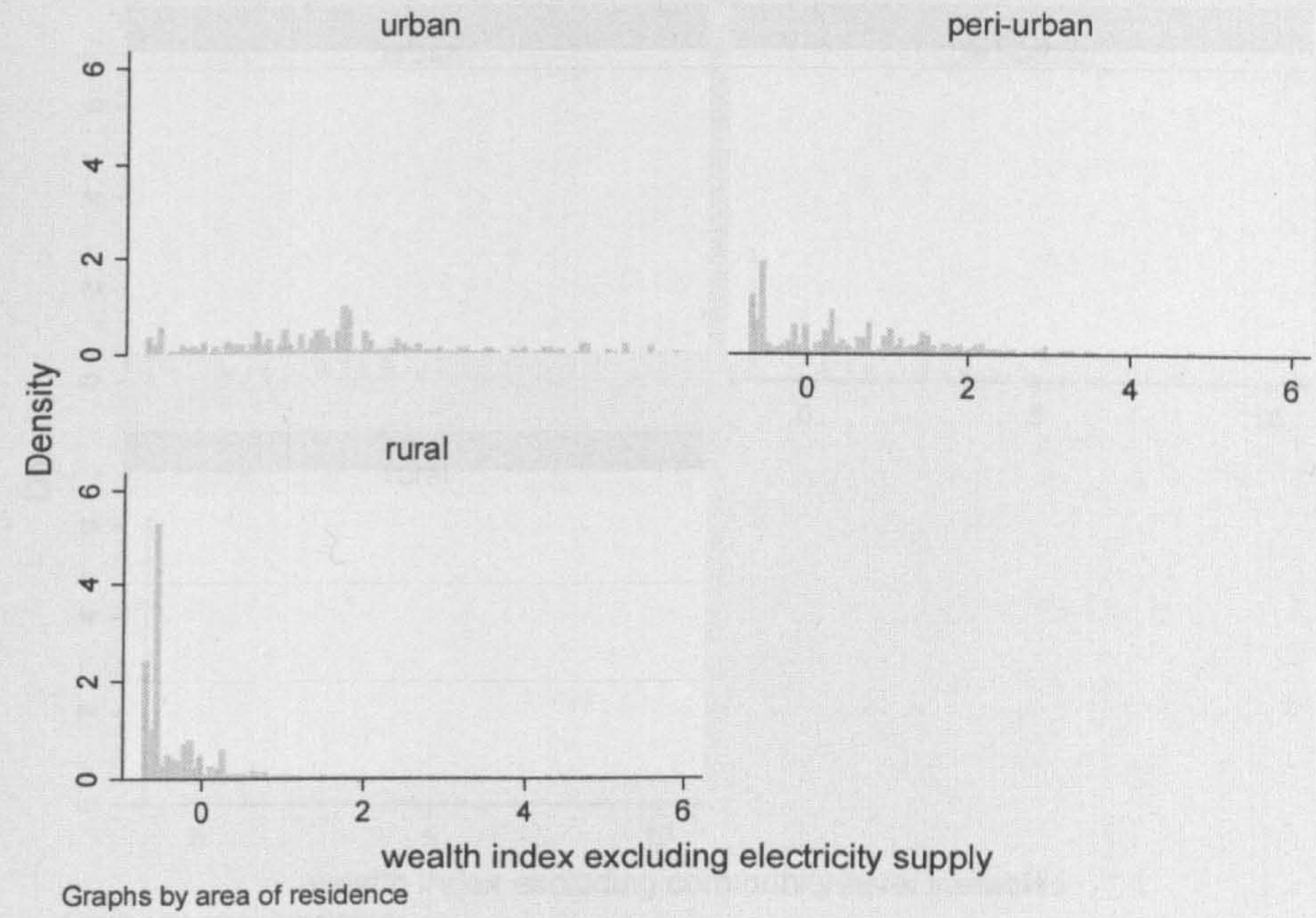


Figure 6.4: Distribution of wealth indices excluding electricity and consumer durables dependent on electricity

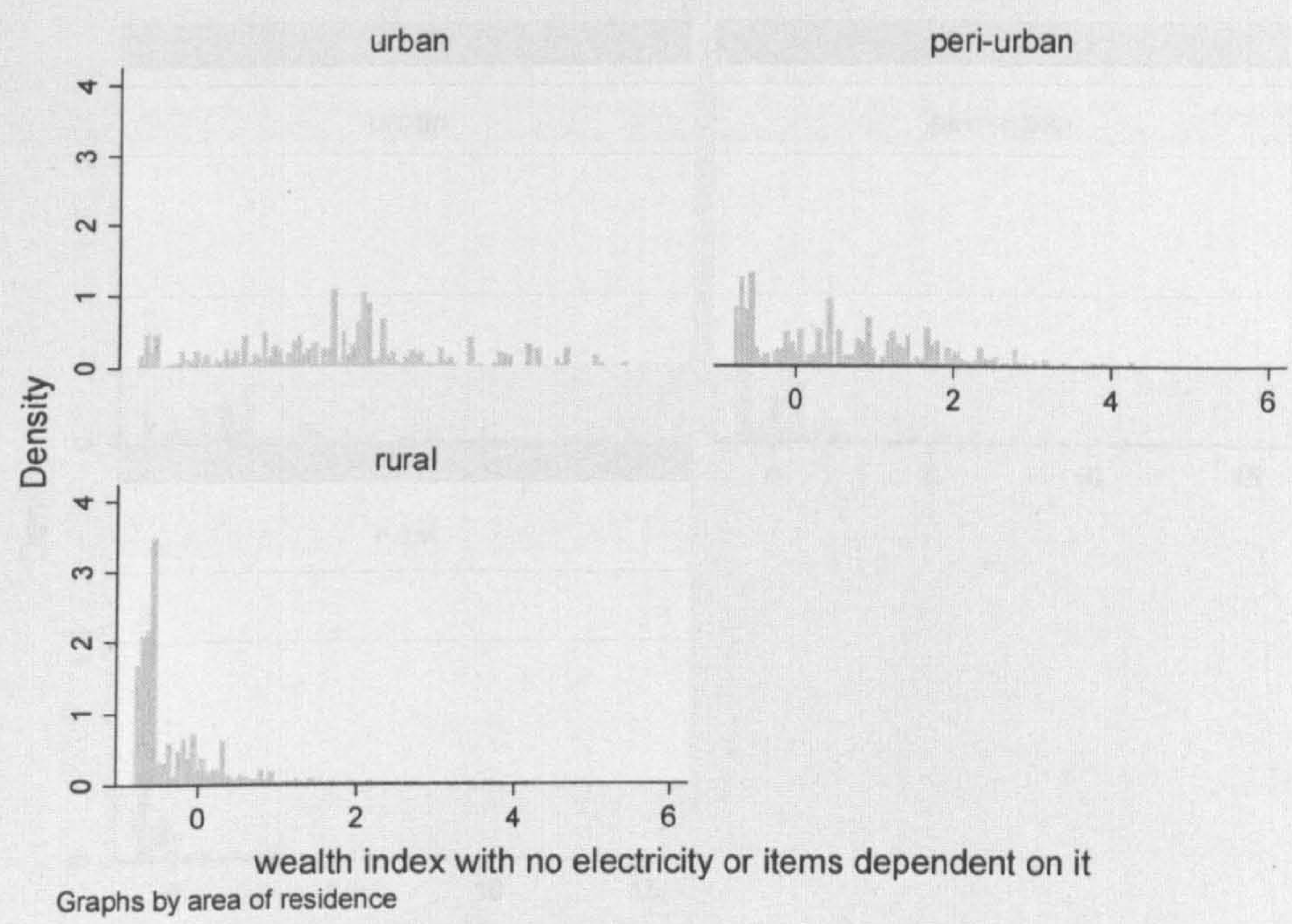


Figure 6.5: Distribution of the wealth index excluding community-level services

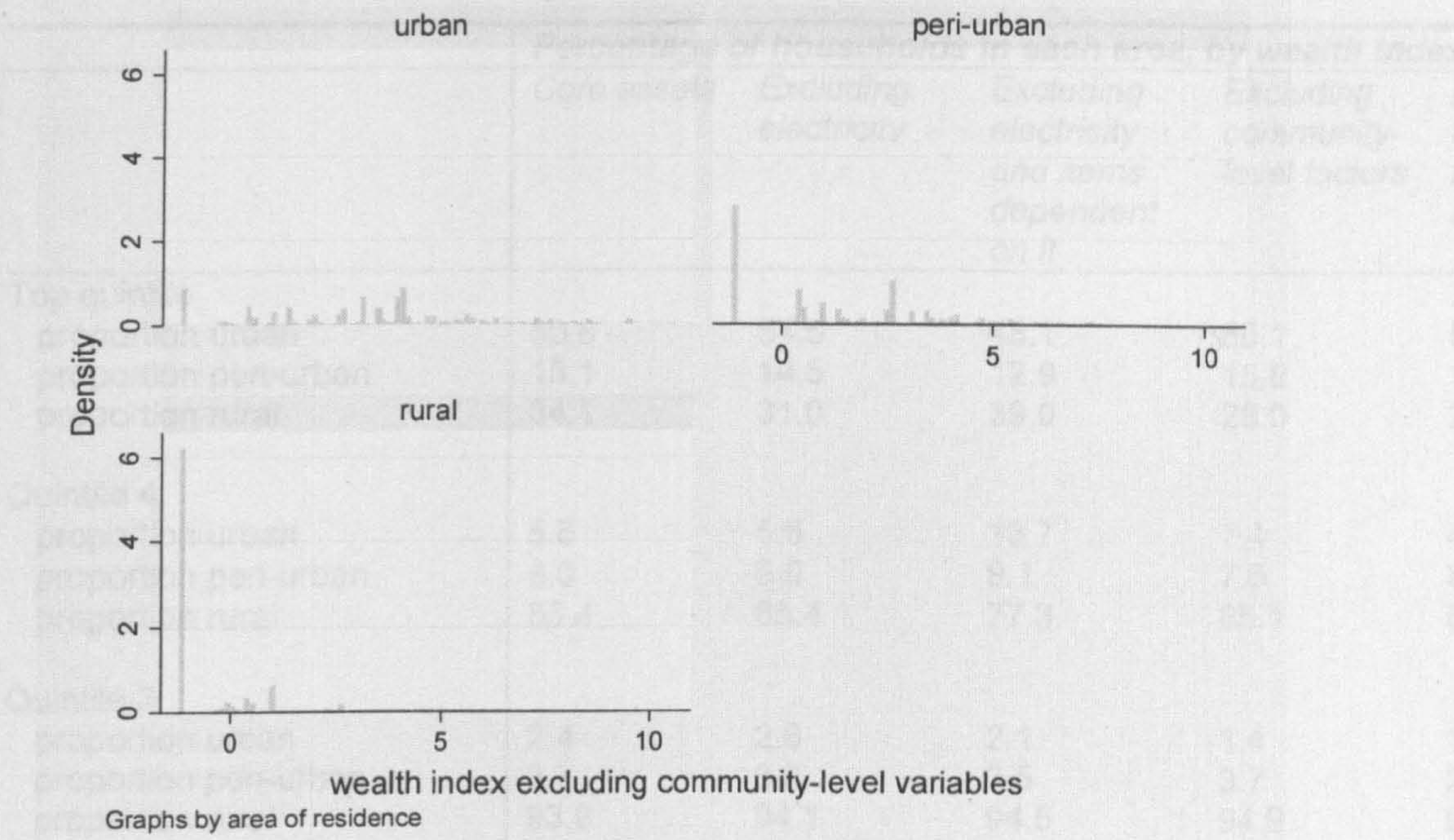


Figure 6.6: Distribution of the wealth index excluding housing-related items

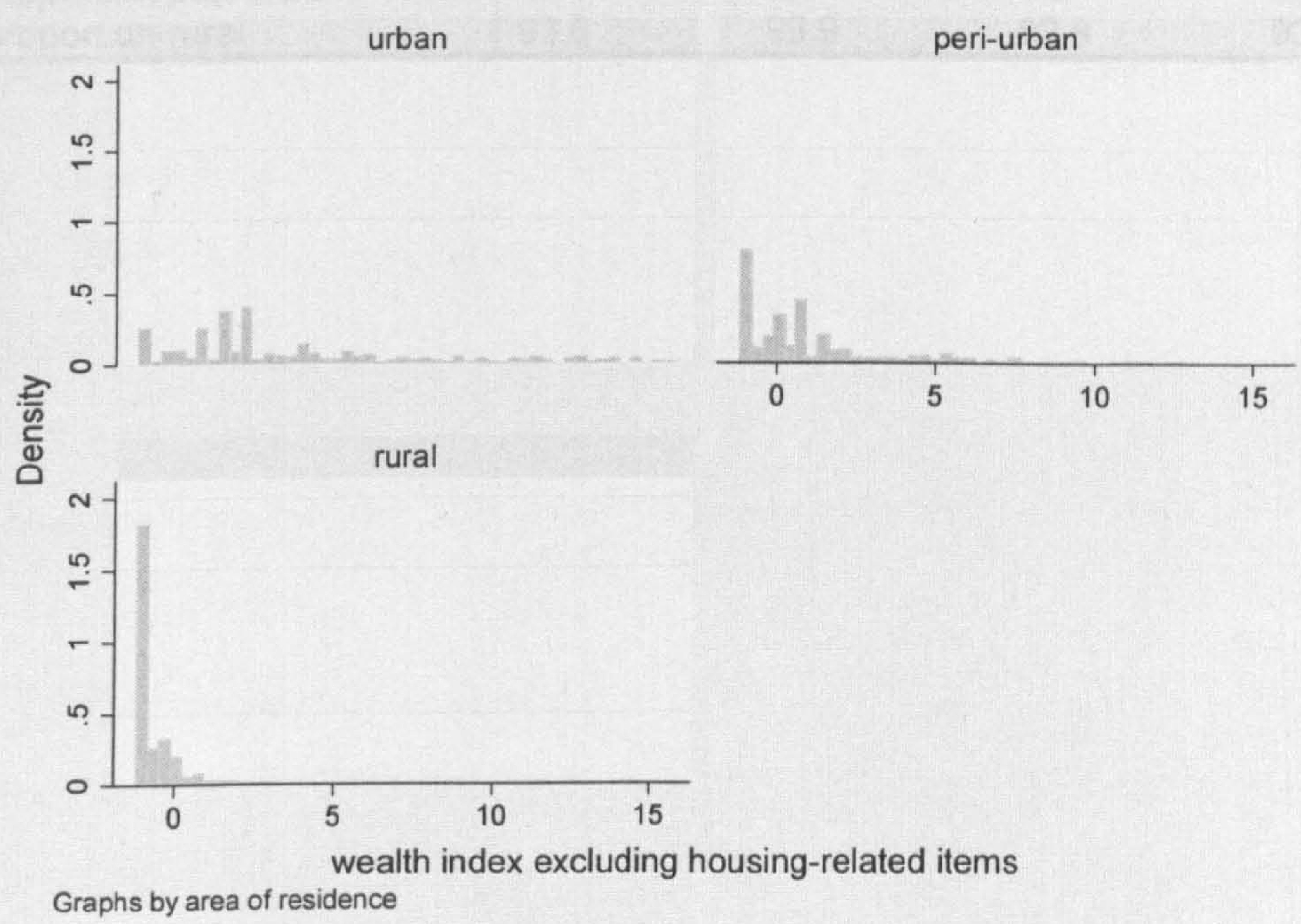


Table 6.12: The percentage of urban, peri-urban and rural households within each quintile of wealth indices

	Percentage of households in each area, by wealth index quintile				
	Core assets	*Excluding electricity*	*Excluding electricity and items dependent on it*	*Excluding community-level factors*	*Excluding housing-related items*
Top quintile					
proportion urban	50.8	54.5	48.1	56.1	55.7
proportion peri-urban	15.1	14.5	12.9	15.8	14.7
proportion rural	34.1	31.0	39.0	28.0	29.6
Quintile 4					
proportion urban	5.6	5.6	13.7	7.4	4.9
proportion peri-urban	8.0	9.0	9.1	7.6	8.8
proportion rural	86.4	85.4	77.3	85.1	86.3
Quintile 3					
proportion urban	2.4	2.6	2.1	1.4	1.1
proportion peri-urban	3.7	3.2	3.5	3.7	2.9
proportion rural	93.9	94.1	94.5	94.9	96.1
Quintile 2					
proportion urban	1.3	1.3	1.6	1.8	1.5
proportion peri-urban	2.9	2.9	3.6	2.9	3.0
proportion rural	95.8	95.9	94.8	95.3	95.5
Bottom quintile					
proportion urban	2.3	2.5	3.0	2.3	2.8
proportion peri-urban	4.1	3.6	4.2	3.8	3.6
proportion rural	93.6	93.9	92.9	93.9	93.6

Table 6.13: Agreement between classification into quintiles of per capita consumption expenditure and wealth indices

	% Households moving between quintiles of wealth index and per capita consumption expenditure					
Index	*Same quintile*	*Move 1 quintiles*	*Move 2 quintiles*	*Move 3 quintiles*	*Move 4 quintiles*	*Kappa (SE)*
Core assets						
Whole population (n=11243)	28.9	33.5	20.4	13.6	3.6	0.11 (0.005)
Urban areas (n=1434)	54.7	24.0	12.7	6.6	2.1	0.16 (0.01)
Peri-urban areas (n=739)	37.5	35.4	14.7	10.7	1.8	0.13 (0.02)
Rural areas (n=9070)	24.1	34.9	22.1	15.0	4.0	0.05 (0.005)
Excluding electricity						
Whole population (n=11257)	28.8	33.7	20.2	13.8	3.6	0.10 (0.005)
Urban areas (n=1434)	54.7	23.9	12.8	6.6	2.1	0.13 (0.01)
Peri-urban areas (n=739)	37.5	35.1	14.4	11.0	2.0	0.14 (0.02)
Rural areas (n=9084)	23.9	35.1	21.9	15.1	3.9	0.048 (0.005)
Excluding electricity and consumer durables dependent on it						
Whole population (n=11264)	28.4	33.6	20.6	13.2	4.2	0.10 (0.005)
Urban areas (n=1436)	52.8	27.3	12.3	6.0	1.7	0.14 (0.01)
Peri-urban areas (n=739)	35.6	33.3	16.6	11.5	3.1	0.12 (0.02)
Rural areas (n=9089)	23.9	34.7	22.3	14.5	4.7	0.050 (0.005)
Excluding community-level services						
Whole population (n=11271)	29.4	33.9	21.0	11.8	4.0	0.11 (0.005)
Urban areas (n=1438)	56.3	23.0	12.2	6.5	2.0	0.14 (0.01)
Peri-urban areas (n=740)	40.6	30.8	16.0	9.0	3.6	0.16 (0.02)
Rural areas (n=9093)	24.2	35.9	22.8	12.9	4.3	0.060 (0.005)
Excluding housing-related items						
Whole population (n=11245)	28.0	32.6	20.9	14.2	4.3	0.099 (0.005)
Urban areas (n=1434)	54.7	22.6	13.0	7.3	2.4	0.13 (0.01)
Peri-urban areas (n=739)	36.3	34.9	16.2	10.0	2.6	0.13 (0.02)
Rural areas (n=9072)	23.0	34.0	22.6	15.7	4.7	0.042 (0.005)

Table 6.14: Increased, decreased or unchanged ranking of households between quintiles of per capita consumption expenditure and wealth indices

Index	*Lower quintile by wealth index*	*Same quintile*	*Higher quintile by wealth index*
Core assets			
Whole population (n=11243)	42.6	28.9	28.4
Urban areas (n=1434)	7.6	55.0	37.4
Peri-urban areas (n=739)	28.8	37.4	33.8
Rural areas (n=9070)	49.4	24.1	26.5
Excluding electricity			
Whole population (n=11257)	43.5	28.7	27.8
Urban areas (n=1434)	8.0	54.5	37.5
Peri-urban areas (n=739)	29.3	37.5	33.2
Rural areas (n=9084)	50.3	23.9	25.8
Excluding electricity and consumer durables dependent on it			
Whole population (n=11264)	43.9	28.3	27.8
Urban areas (n=1436)	14.4	52.7	32.9
Peri-urban areas (n=739)	35.2	35.6	29.2
Rural areas (n=9089)	49.3	23.8	26.8
Excluding community level services			
Whole population (n=11271)	44.2	29.4	26.5
Urban areas (n=1438)	8.0	56.2	35.8
Peri-urban areas (n=740)	28.1	40.6	31.4
Rural areas (n=9093)	51.3	24.1	24.6
Excluding housing-related items			
Whole population (n=11245)	43.9	27.9	28.2
Urban areas (n=1434)	8.2	54.5	37.3
Peri-urban areas (n=739)	30.1	36.3	33.7
Rural areas (n=9072)	50.8	22.9	26.3

6.5.6 Discussion

Removing key urban-bias indicators from the wealth index had few, if any, of the hypothesised effects on the area-patterns of wealth index characteristics. This implies that the strong area-patterning of wealth index scores and the overestimation of urban households' SEP by the wealth index compared with consumption expenditure are not strongly driven by the few indicators excluded from these wealth indices. This may be because all of the indicators are strongly patterned across the areas. It may, however, be the case that the wealth index is capturing urban-rural disparities in cash resources more accurately than consumption expenditure. The expenditure measure is calculated using complex assumptions and adjustments for home-produced goods and goods received in kind. Thus two households which purchased or produced the same amount of food stuff would have the same food consumption expenditure, despite perhaps substantial differences in disposable income that may be reflected in differences in wealth index scores. Given the results of these analyses, there is little reason to recommend the exclusion of electricity, public services, or housing-related indicators from the wealth index, unless the research hypothesis of interest concerns the direct effects of these factors.

6.6 *Approaches to looking separately at urban, peri-urban and rural areas*

6.6.1 Background

In analyses of DHS data, a single wealth index was created for the entire country sample, which was then divided into quintiles and subsequently stratified into urban and rural areas.[56] This would be one possibility for conducting analysis separately by area. A further option would be to create separate indices for urban and rural areas, such that the indicators are given different weights in each area. The consequences of choosing one or another approach have not been explored.

6.6.2 Objectives

1. Explore the consequences of generating separate wealth indices for urban, peri-urban and rural areas

6.6.3 Hypotheses

1. Generating wealth indices separately for types of area may result in indices with less clumped distributions, particularly in rural areas, since the assets' weights will be determined based on their importance in the restricted area rather than in the whole population and so the index should have an improved ability to rank households in that area
2. Generating wealth indices separately for types of area may result in an improved agreement with consumption expenditure compared with a whole population index, because as above, the indices will be constructed using the information about differences in asset ownership within the restricted area rather than across the whole population

6.6.4 Methods

Separate indices are generated for urban, peri-urban and rural areas for both Malawi and Brazil, using the core sets of assets. The whole population wealth index is compared with these separate indices in terms of distribution and, for Malawi, agreement with consumption expenditure.

6.6.5 Results

6.6.5.1 Weights assigned to indicators

The weights assigned to each index component for the whole population index and the separate indices for urban, peri-urban and rural areas are shown for both Malawi and Brazil in **Table 6.15**. In Malawi, the first principal component explains a slightly lower proportion of the total variance in the peri-urban index (15.5%) compared with the whole population index (18.9%) and the urban index (18.6%). The proportion of total variance explained by the first principal component in the rural index is lower still (12.8%). All of these figures are quite low, but comparable with other studies. The pattern is reversed in Brazil, where the proportion of total variance explained by the first principal component is lowest in urban areas, intermediate in peri-urban areas, and highest in rural areas.

The weights differ to some extent between the indices. In Malawi, radio has a negative weight in the urban index, and a positive weight in the peri-urban and rural indices. The weight assigned to bicycle ownership is also higher in rural areas, indicating that this is a better differentiator of SEP in rural compared with urban areas. In contrast, car ownership and domestic servants are assigned considerably higher weights in urban areas compared with peri-urban and rural areas. Contrary to what might be expected, electricity has a similar weight across all areas. Surprisingly, ownership of agricultural land is assigned a negative weight in all indices, including the rural index. In Brazil, electricity is assigned a far higher weight in the rural index compared with the urban index, since a very high proportion of urban households have an electricity supply. Differences in the weights assigned to categories of categorical variables also reflect the variability in each area of the indicators; for instance flush toilet is assigned a lower weight in the rural index compared with the urban index, since the vast majority of rural households do not have a flush toilet.

Table 6.15: Weights assigned to index items in the wealth indices using the core assets; whole population index and separate indices for urban, peri-urban and rural areas

A: Malawi

Asset	Whole population index	Urban index	Peri-urban index	Rural index
% variance explained by first principal component	*18.9*	*18.6*	*15.5*	*12.8*
Has electricity	0.3426	0.3466	0.3415	0.3436
Has radio	0.0194	-0.0658	0.1341	0.1045
Has television/VCR	0.2835	0.3272	0.2781	0.2549
Has bicycle	0.0026	0.0082	0.0893	0.1219
Has motorbike/scooter	0.0432	0.0577	0.0714	0.0603
Has car	0.1887	0.2659	0.1330	0.1359
Has domestic servant	0.1425	0.2248	0.1508	0.1051
Owns agricultural land	-0.2279	-0.0512	-0.1345	-0.1465
Drinking water source				
Piped into dwelling	0.2762	0.3548	0.2055	0.3022
Piped outside dwelling	0.1630	0.0721	0.1595	0.1061
Communal standpipe	0.1250	-0.1162	0.0600	0.1080
Personal handpipe/well	0.0154	-0.0522	0.0641	0.0342
Communal handpipe/well	-0.2269	-0.1826	-0.1923	-0.1410
River/spring/lake/reservoir/ Other	-0.0433	-0.0255	-0.0860	-0.0342
Toilet facility				
Flush toilet	0.2760	0.3536	0.2360	0.2811
VIP latrine	0.0893	0.0291	0.1071	0.1611
Traditional latrine with roof	0.0014	-0.1368	0.0926	0.0237
Traditional latrine no roof	-0.0611	-0.1260	-0.1552	-0.0548
None or other	-0.0923	-0.0702	-0.1700	-0.0928
Material of dwelling floor				
Sand	-0.0078	-0.0272	-0.0196	0.0249
Smoothed mud/other	-0.3116	-0.2748	-0.3774	-0.3383
Smooth cement/wood/tiles	0.3313	0.2786	0.3897	0.3629
Cooking fuel				
Collected firewood	-0.3047	-0.1679	-0.3043	-0.3129
Purchased firewood	0.1251	-0.1133	0.1686	0.2510
Paraffin/gas/charcoal	0.2194	0.0363	0.1449	0.1485
Electricity	0.2452	0.3129	0.1766	0.2267
Crop residue/sawdust/ other	0.0042	-0.0217	0.0079	0.0427

B: Brazil

Asset	Whole population	Urban index	Peri-urban index	Rural index
% variance explained by first principal component	*12.1*	*9.8*	*10.5*	*11.5*
Has electricity	0.2540	0.0406	0.1427	0.3060
Has radio	0.1662	0.1780	0.1659	0.1525
Has television	0.3096	0.2858	0.3181	0.2960
Has fridge	0.3173	0.2526	0.3067	0.3490
Has car	0.2208	0.2631	0.2624	0.2276
Has domestic servant	0.0252	0.0200	0.0130	0.0285
Drinking water source				
Piped into dwelling	0.2471	0.1446	0.2101	0.1530
Piped into yard/plot	-0.0930	-0.1536	-0.1520	-0.0272
Well/spring inside	-0.1230	-0.0775	-0.1121	0.0884
Well/spring outside	-0.1575	-0.1021	-0.0958	-0.1384
Bottled water	0.0669	0.0622	0.0683	0.0207
Other	-0.1200	-0.0816	-0.0954	-0.1279
Toilet facility				
Toilet to sewer	0.2335	0.2722	0.2500	0.0927
Toilet to open space	-0.0456	-0.0882	-0.0742	0.0198
Toilet to river/lake	-0.0094	-0.0463	-0.0052	0.0563
Latrine to sewer	0.0712	0.0210	0.0570	0.0867
Latrine not connected	0.0095	-0.1226	-0.0214	0.1870
Traditional latrine	-0.0863	-0.1454	-0.1589	0.1109
No facility	-0.2818	-0.1614	-0.2120	-0.3423
Other	-0.0099	0	-0.0057	-0.0154
Material of dwelling floor				
Earth/sand	-0.2240	-0.1095	-0.1729	-0.2817
Wood planks	0.0017	-0.0698	-0.0199	0.0985
Polished wood	0.0837	0.0700	0.1098	0.1700
Vinyl	0.0310	0.0311	0.0424	0.0425
Ceramic tiles	0.2219	0.2541	0.2449	0.1633
Cemento	-0.1643	-0.2766	-0.2402	-0.0096
Carpet	0.0769	0.0962	0.0864	0.0595
Other	-0.0182	0.0247	-0.0012	-0.0402
Wall material				
Palm/straw	-0.0627	-0.0185	-0.0308	-0.0766
Unpolished mud	-0.2057	-0.1145	-0.1496	-0.2396
Raw wood	-0.0835	-0.1788	-0.1251	-0.0322
Alvanaria	0.1922	0.2463	0.1976	0.0883
Polished wood	-0.0488	-0.1361	-0.0925	0.1619
Other	-0.0100	-0.0035	-0.0270	0
Roof material				
Palm/straw	-0.1367	-0.0169	-0.0613	-0.1740
Raw wood	-0.0191	-0.0500	-0.0013	-0.0177
Clay tiles	-0.2102	-0.2370	-0.2337	-0.1200
Concrete	0.2634	0.3446	0.2909	0.1392
Zinc	-0.0402	-0.1254	-0.0751	0.0410
Polished wood	0.0628	0.0053	0.0921	0.1960
Eternit/Amianto	-0.0137	-0.1133	-0.0649	0.0300
Other	-0.0226	-0.0006	-0.0333	-0.0462
Persons per sleeping room	-0.1114	-0.1699	-0.1550	-0.1066

6.6.5.2 Distribution of the indices

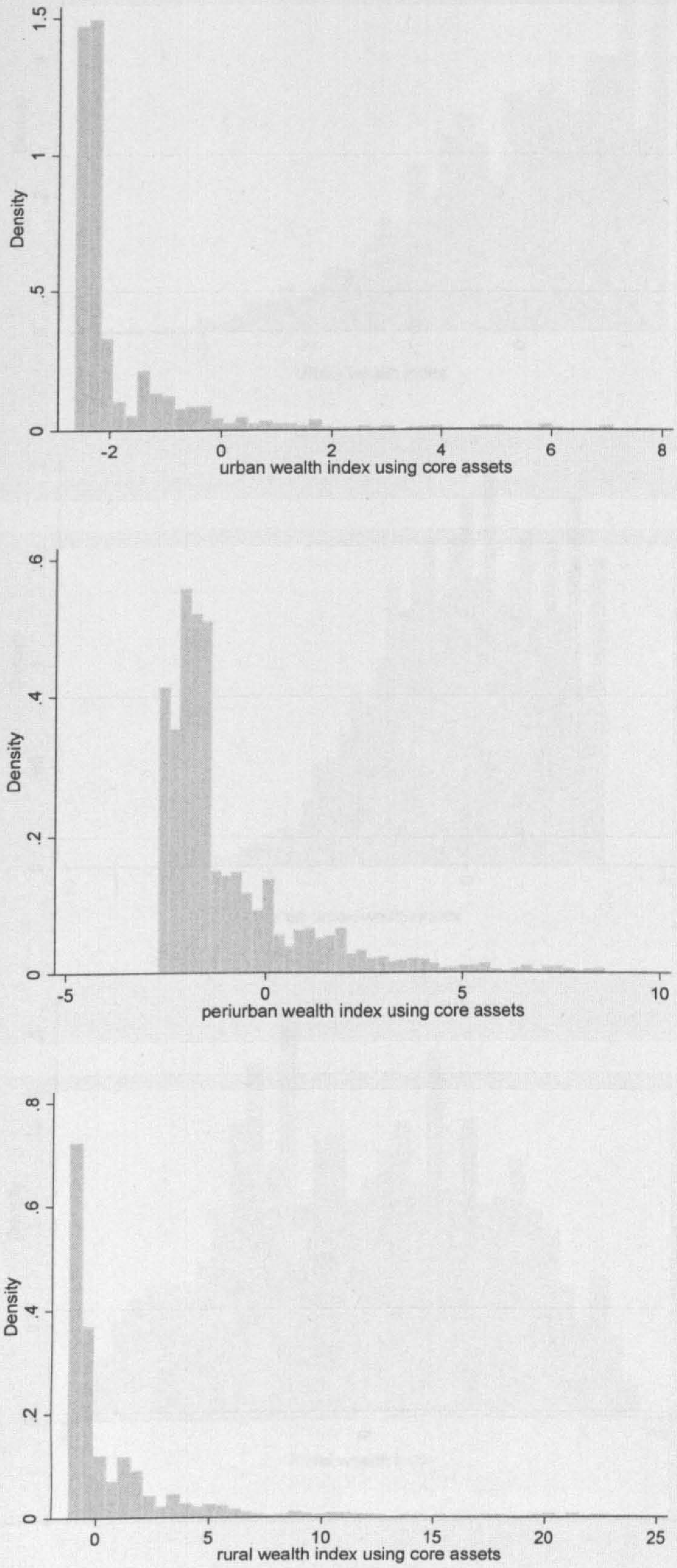
Generating separate indices for urban, peri-urban and rural areas did not result in improvements to clumping or truncation (in comparison with the whole population index shown in **Figure 6.2**) in either Malawi or Brazil (**Figure 6.7**). Whilst there is little change in the extent of clumping observed in rural areas of Malawi, the separate indices appear to have *more* clumping at lower values for peri-urban areas and urban areas. The distributions in Brazil are little changed.

6.6.5.3 Agreement with per capita consumption expenditure

Creating separate wealth indices for urban, peri-urban and rural areas does not improve the agreement of the wealth index with consumption expenditure when compared with the whole population index (**Table 6.16**).

Figure 6.7: Distributions of separate wealth indices using core assets for urban, peri-urban, and rural areas

A: Malawi



B: Brazil

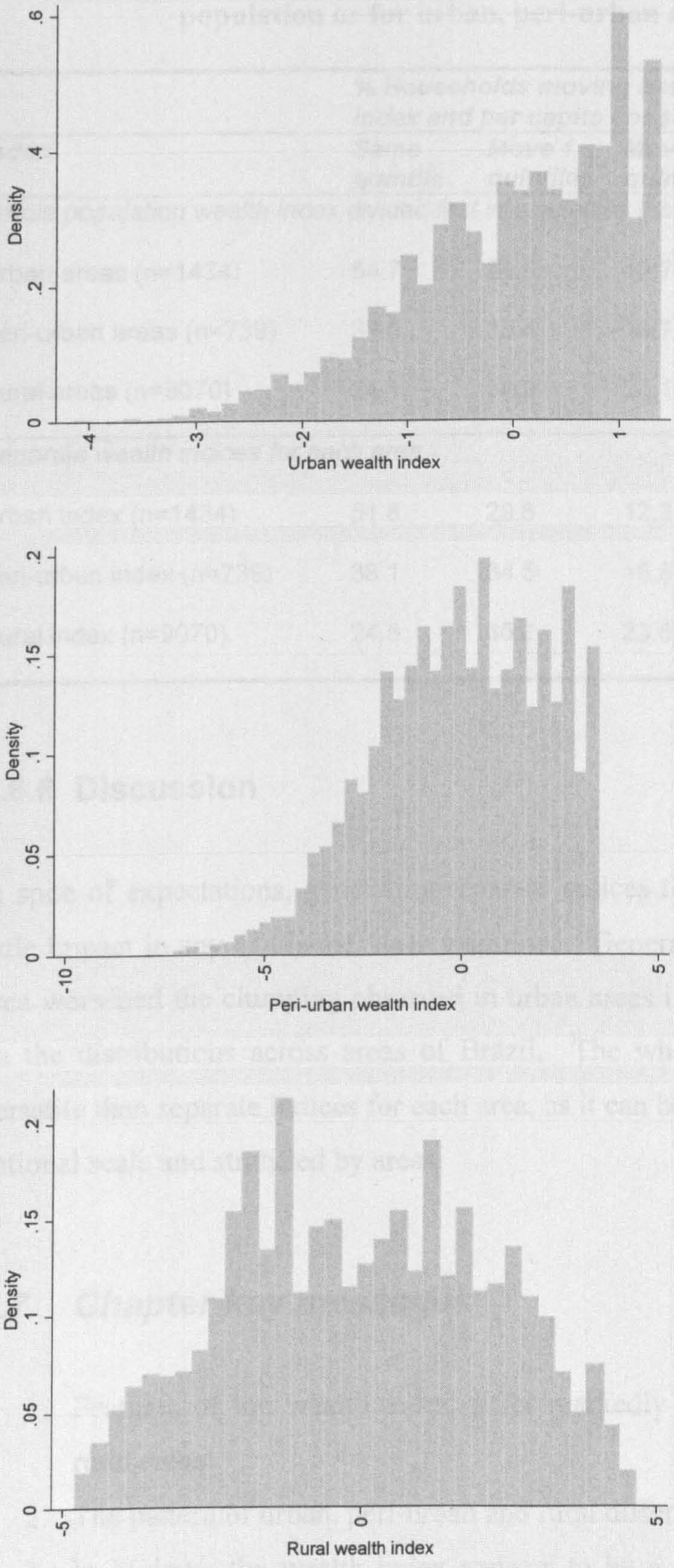

Density
Urban wealth index
Density
Peri-urban wealth index
Density
Rural wealth index

Table 6.16: Agreement between classification into quintiles of per capita consumption expenditure and wealth indices for the whole population or for urban, peri-urban and rural areas

	% Households moving between quintiles of wealth index and per capita consumption expenditure					
Index	*Same quintile*	*Move 1 quintiles*	*Move 2 quintiles*	*Move 3 quintiles*	*Move 4 quintiles*	*Kappa (SE)*
Whole population wealth index divided first into quintiles then stratified by area						
Urban areas (n=1434)	54.7	24.0	12.7	6.6	2.1	0.16 (0.01)
Peri-urban areas (n=739)	37.5	35.4	14.7	10.7	1.8	0.13 (0.02)
Rural areas (n=9070)	24.1	34.9	22.1	15.0	4.0	0.05 (0.005)
Separate wealth indices for each area						
Urban index (n=1434)	51.8	29.6	12.3	5.6	0.75	0.18 (0.02)
Peri-urban index (n=739)	38.1	34.5	16.8	8.8	1.8	0.15 (0.02)
Rural index (n=9070)	24.5	35.2	23.5	12.8	4.1	0.06 (0.005)

6.6.6 Discussion

In spite of expectations, generating separate indices for each type of area had very little impact in any of the measures examined. Generating separate indices for each area worsened the clumping observed in urban areas in Malawi, but had little effect on the distributions across areas of Brazil. The whole population index is more versatile than separate indices for each area, as it can be used for analysis both on the national scale and stratified by areas.

6.7 Chapter key messages

1. Features of the wealth index differ markedly across urban, peri-urban and rural areas
2. The pattern of urban, peri-urban and rural differences is context-specific
3. In Malawi, the wealth index appears to be a weak tool for identifying the urban poor and rural wealthy. There is some indication from the distributions of the Brazil wealth index that in this context it is the urban wealthy that the

wealth index struggles to separate out, but this cannot be confirmed in the absence of expenditure data

4. The wealth index tends to overestimate the SEP of urban households compared with consumption expenditure, and vice versa for rural households
5. Removing indicators hypothesised to have a particularly strong urban bias had relatively little impact on the area-specific features of the wealth index
6. Constructing separate wealth indices for urban, peri-urban and rural areas does not necessarily result in an improved ability to differentiate between the SEP of households within an area, and can in some cases increase the clumping observed in the wealth index distribution

6.8 Next steps

This work has explored the effect of area on the wealth index, and whether this is affected by urban-biased indicators. This work has used only those indicators used in wealth indices in the DHS. The DHS acknowledge that these indicators were selected because of availability, and may not be the most appropriate indicators. The next step in this thesis is therefore to go on to explore the consequences of using a wider range of indicators.

7. Choice of indicators for a wealth index

This chapter explores the effects of expanding the set of indicators commonly used to construct a wealth index. The consequences of incorporating different types of indicators are explored in terms of the wealth index's distribution, urban-rural patterns, and agreement with consumption expenditure. The types of variables added to the standard set of indicators are: productive assets, a wider range of consumer durables and public services, human capital indicators, demographics, and finally measures of subjective SEP.

7.1 Background

The indicators used in the DHS wealth indices were selected from the available indicators in the DHS surveys; those proposing the methodology recognise that they may not be the ideal indicators.[58] Despite this, these indicators have also become those most commonly used for wealth indices in primary data collection. It is possible that a greater number or broader range of types of indicators may allay some of the concerns about using the wealth index – the clumping and truncation of its distribution, or its poor agreement with consumption expenditure, for example. Increasing the number of indicators used to construct the wealth index would be expected to improve the distribution of the wealth index score, reducing truncation and/or clumping as long as the additional indicators are unequally distributed in the population. This change is only a useful alteration to the wealth index if the additional indicators are meaningful in terms of SEP.

Productive assets, i.e. those that can be used for income-generation such as agricultural land, farming equipment, and livestock may be important indicators of SEP. This may be particularly true in rural areas, where more households are subsistence farmers. Inclusion of productive assets in a wealth index may therefore improve the ability of a wealth index to measure SEP in rural areas, perhaps increasing its agreement with consumption expenditure and improving the ability of the wealth index to differentiate between poor and less poor rural households.

Productive assets could, however, be viewed as determinants of SEP rather than indicators of it.[65, 283] For this reason, some may not consider it appropriate to include them in a wealth index in the same way as indicators of SEP such as consumer durables. PCA cannot make a distinction between variables with different hypothesised relationships to the underlying concept being measured, although some latent variable approaches to wealth index construction can differentiate between determinants and indicators of SEP.[94]

The number of indicators included in the DHS wealth index is limited mainly by data availability. One solution to the concern about the wealth index's ability to differentiate between the rural poor in Malawi and similar settings could be to include more indicators to gain additional variation between households. Items more likely to be owned in rural areas could also be included, for instance basic household items such as a bucket or chair. There was some indication from the systematic review presented in **Chapter 3** that wealth indices with longer lists of indicators had stronger relationships with consumption expenditure.

Socio-economic position is a complex construct with varying definitions. Whilst most have viewed the wealth index as an attempt to proxy the monetary measure of consumption expenditure, some would view it as capturing a wider concept of SEP. Therefore some researchers have included human capital and demographic variables in wealth indices, in particular, several studies have included education (generally of the household head).[115, 289, 295] In addition to being an integral part of a broader concept of SEP, human capital and demographic factors are important determinants of the economic aspects of SEP, for instance education levels determine earning potential, female-headed households may have decreased earning potential, individuals who do not speak the majority language may be excluded from certain jobs, and so on. Human capital and demographic factors are therefore important determinants of permanent income, the underlying concept which many view consumption expenditure as measuring, and their inclusion in a wealth index could improve its agreement with consumption expenditure.[94]

Decisions about whether to include or exclude human capital and demographic indicators from a wealth index seem to be lacking a methodological or theoretical basis, and are generally not justified in research papers. There is some evidence from the systematic review presented in **Chapter 3** that inclusion of demographic and human capital variables in a wealth index may increase its association with consumption expenditure, but this has until now not been explored in a systematic way within one dataset. It is worth noting that only household level variables can be included in a household wealth index, so human capital and demographic variables will generally be related to the household head. Whilst the characteristics of other household members are likely to be important for health outcomes in other ways, e.g. a caregiver's education affects child nutritional status through numerous complex pathways, the human capital and demographic characteristics of the household head are likely to be those most relevant to household economic position. There is, however, a strong argument for keeping education separate from the wealth index, since education is a separate exposure in itself and there may be good reason to be interested in the independent effects of education.

Just one study included in the systematic review presented in **Chapter 3** included measures of subjective SEP in the wealth index; this study demonstrated a weak association with consumption expenditure.[122] Measures of food consumption or security were included in three of the studies included in the systematic review, but the effects of their inclusion could not be evaluated thoroughly due to the small number of studies and the differences in the indicators used in each case. Papers do not generally justify the indicators included or excluded from a wealth index; it is likely that indicators of food security and subjective SEP have been included or excluded from wealth indices primarily because of data availability and other reasons that are not theoretically or methodologically grounded. In low-income countries, food makes up by far the largest share of consumption expenditure. It is therefore feasible that inclusion of some simple measure of food consumption could increase the agreement of the wealth index with consumption expenditure. This effect could be most pronounced in rural areas, where food is an even higher proportion of total consumption expenditure. Likewise, subjective measures of SEP are known to be strongly associated with economic position measures and their inclusion in a wealth index may therefore increase its agreement with consumption expenditure.[312]

7.2 Objectives

The overall objective of this chapter is to:

- Explore the impact on features of the wealth index of including a greater number and different types of indicator

Specific objectives are:

1. To explore the effects on wealth index distribution, urban-rural patterns, and agreement with consumption expenditure of including productive assets
2. To explore the effects on wealth index distribution, urban-rural patterns, and agreement with consumption expenditure of including a greater number of consumer durables, and indicators of access to services
3. To explore the effects on wealth index distribution, urban-rural patterns, and agreement with consumption expenditure of including human capital and demographic indicators
4. To explore the effects on wealth index distribution, urban-rural patterns, and agreement with consumption expenditure of including measures of subjective SEP

7.3 Hypotheses

Each set of indicators added to the core set has the potential to:

1. Reduce clumping of the wealth index distribution in rural areas
2. Reduce the observed difference in mean wealth index scores between urban and rural areas
3. Improve the agreement of the wealth index with consumption expenditure
4. Reduce the proportion of rural households that are ranked lower by the wealth index than by consumption expenditure

7.4 Methods

These analyses could only be performed in the Malawi IHS2 data since additional indicators relevant to wealth index construction are not available in the Brazil DHS data. Wealth indices were constructed for the Malawi IHS2 sample, using PCA and taking the first principal component as the measure of SEP. Categorical variables were used as dummy indicators, with one dummy variable for each category. The wealth indices used the core assets (**Section 4.2**) in addition to:

1. Productive assets: sewing machine, ox-cart, barrow, sprayer, total area of land owned, ownership of cattle, goats, sheep, pigs, chickens, other poultry, oxen, other livestock.
2. Additional consumer durables and services: bed, table, chair, lighting fuel, whether any family member sleeps under a bed-net, tape/CD player, fan, air-conditioning, sewing machine, refrigerator, washing machine, working landline telephone, mortar & pestle, sofa, coffee table, cupboard, lantern, desk, clock, clothes iron, working mobile phone, rubbish disposal facilities, crowding index
3. Human capital: education of the household head (highest grade)
4. Human capital and demographics: highest educational grade attended by the head of the household, highest qualification of the head of the household, literacy of head of household, age of head of household, marital status of head of household, sex of head of household, religion of household head, language spoken at home
5. Single subjective measure of SEP: Indicator of food consumption adequacy
6. Multiple subjective measures of SEP: food consumption adequacy, housing adequacy, clothing adequacy, healthcare adequacy, economic ladder question, income adequacy, life satisfaction, changes of clothes, sleeping place, sleeping in cold season

Measurement of human capital and demographic variables

Education in Malawi generally starts at six years old; there are few opportunities for pre-school. There are eight years of primary school, followed by four years of secondary school and then university and technical training colleges. At the end of the eighth year of primary school, students sit Primary School Leaving Certificate (PSLC) examinations, which they must pass in order to attend a government secondary school. There are two qualifications that can be obtained in secondary school: the Junior Certificate Examination (JCE) in the second year and the Malawi School Certificate of Education (MSCE) in the fourth and final year. The highest educational grade of the household head was categorised as none or pre-school/nursery only, partial completion of primary school, completion of primary school, partial or full completion of secondary school, and higher education (including polytechnic, university, and training colleges). Partial and complete secondary school were grouped together because of the very low numbers of individuals starting but not completing secondary school (one household head). The highest educational qualification obtained by the head of household was categorised as none, PSLC, JCE, MSCE, and diploma or higher.

Literacy of the head of household was measured as the self-reported ability to read a one-page letter in Chichewa or in English. Age of the head of household was used as a continuous variable. Marital status of the head of household was categorised as monogamous marriage or non-formal union, polygamous marriage or non-formal union, separated/divorced, widowed, or never married. The main language spoken in the household was categorised as Chichewa, Nyanja, Yao, Tumbuka, or any other language. Religion of the household head was categorised as none, traditional, Islam, Catholic, Church of Central Africa Presbyterian (CCAP), or other Christian.

Measurement of subjective SEP indicators

Details of the subjective measures of SEP are given in **Box 7.1**; number of changes of clothes was used as a continuous variable, all others were used as dummy indicators.

Box 7.1: Subjective measures of SEP in IHS2

All questions are asked of the household head; coding is shown in parentheses

Food consumption adequacy: Was the household's food consumption over the past month less than adequate (1), just adequate (2), or more than adequate (3) for the household's needs?

Housing adequacy: Is your housing less than adequate (1), just adequate (2), or more than adequate (3) for the household's needs?

Clothing adequacy: Is your clothing 1 less than adequate (1), just adequate (2), or more than adequate (3) for the household's needs?

Healthcare adequacy: Is the level of healthcare household members receive less than adequate (1), just adequate (2), or more than adequate (3) for the household's needs?

Economic ladder question: Imagine six steps where on the bottom (1=1st step) stand the poorest people and on the top (6=6th step) stand the richest people. On which step are you today?

Income adequacy: Which of the following is true about your current income: allows you to build your savings (1), allows you to save just a little (2), only just meets your expenses (3), is not sufficient so you need to use your savings to meet expenses (4), is really not sufficient so you need to borrow to meet expenses (5).

Life satisfaction: Overall, how satisfied are you with your life: very unsatisfied (1), unsatisfied (2), neither unsatisfied nor satisfied (3), satisfied (4), very satisfied (5).

Changes of clothes: How many changes of clothes do you have?

Sleeping place: What do you sleep on? (1=bed and mattress, 2=bed and mat, 3=bed alone, 4=mattress on floor, 5=grass mat on floor, 6=cloth/sack on floor/nothing)

Sleeping in cold season: What do you sleep under in cold season? (1=blanket and sheets, 2=blanket only, 3=sheets only, 4= fertiliser/grain sack, 5=cloth/clothes/nothing)

The prevalence, missing data levels, and urban-rural distribution of all of the additional indicators was assessed using cross-tabulations, and are presented in **Appendix C.**

Analyses of wealth indices

The distribution of the indices was assessed graphically. The urban/peri-urban/rural composition of quintiles of the indices was examined, as was the mean score of the index in each area. The agreement of the wealth indices with per capita consumption expenditure was assessed by examining the proportion of households differentially classified into quintiles of the two measures and calculating Kappa statistics. Analyses were conducted overall and stratified by urban/peri-urban/rural residence in order to evaluate whether the impact of this approach differed between the areas. Inequalities in stunting were also calculated for each wealth index construction, but since these are not key to the objectives of this work, they are presented in **Appendix D**.

7.5 Results

7.5.1 Including productive assets

Contrary to the initial hypothesis, many of the productive assets are in fact owned with higher prevalence in urban areas than in rural areas (**Appendix C**). Urban households own on average more small livestock such as chickens compared with rural households, but fewer larger livestock such as cattle, goats and pigs. The area of land owned tends to be higher in rural areas compared with urban areas. There are substantially higher levels of missing data with regards to productive assets compared with the core assets. 4223 households had missing data for the final wealth index including productive assets (37.4%). Households with missing data for productive assets were more likely to be from urban areas, and had higher than average consumption expenditure. Although it is likely that many of the urban households with missing data did not own the assets, this cannot be assumed since there are no relevant skip patterns in the questionnaire.

Inclusion of productive assets resulted in a substantial decrease of the proportion of the total variance explained by the first principal component (**Table 7.1A**). The magnitude of most of the weights for the core assets was unaffected, with the notable exceptions of bicycle and radio ownership, which had far larger weights in the index including productive assets. Ownership of agricultural land was still assigned a negative weight in the index including productive assets, but the magnitude of the weight was approximately half that in the index including only core assets. Most of the productive assets were assigned positive weights, as would be expected, with the exception of number of pigs owned and area of land owned, which both had negative weights. Excluding those productive assets with negative or low positive weights made very little difference to any of the analyses in this section.

There is some indication that the extent of clumping is slightly reduced in this index compared with the index including core assets only, although substantial clumping remains (**Figure 7.1A**).

The difference between the mean scores in urban and rural areas is 8.4% less in the wealth index including productive assets compared with the core wealth index (**Table 7.2**). Thus including productive assets has gone some way to reducing the observed difference in living standards between urban and rural households.

A notable difference between the core wealth index and the index including productive assets is that with the addition of productive assets, the proportion of households in the top quintile that are from rural areas doubles from 34% to 73% (**Table 7.3**). The composition of the lower quintiles remains unchanged between the two indices; most of the change appears to be households moving between the fourth and top quintiles, with some urban households moving down and some rural households moving up.

Including productive assets in the wealth index does not improve agreement with consumption expenditure (**Table 7.4**). Including productive assets in the wealth index did have an effect on whether the wealth index ranked households as higher than or lower than by consumption expenditure in different areas (**Table 7.5**). In rural areas, there was, in support of the initial hypothesis, an increase in the proportion of households ranked higher by the wealth index compared with consumption expenditure. There was also, however, an increase in the proportion of urban and peri-urban households ranked higher by the wealth index than by consumption expenditure.

The households that do not own productive assets are likely to fall into two main groups: i) poor rural households that cannot afford the item, and ii) urban households that do not engage in agriculture. Using these items in a wealth index for both urban and rural households could result in confusion of these groups and the relationship of the productive assets to other indicators. It may, therefore, only be appropriate to include productive assets in a wealth index for rural areas only. I have, however, explored this possibility, and found that the index did not result in different patterns to those described here for the mixed urban-rural index (data not presented).

7.5.2 Including additional consumer durables and services

Missing data levels for the additional indicators are low (**Appendix C**), and the final wealth index including additional consumer durables and services is missing for just 0.87% of households. Almost all of the additional indicators are owned with higher prevalence in urban areas compared with peri-urban and rural areas (**Appendix C**).

The proportion of variance explained by the first principal component is very slightly reduced when the additional items are included in the wealth index (**Table 7.1B**). The magnitude of the weights for the core assets remains fairly similar, with some exceptions. Generally, where there is a difference between weights, those items more relevant to rural life have an increased weight in the wealth index including additional indicators, e.g. bike and radio. Ownership of agricultural land still has a negative weight in the index including additional indicators, but the magnitude of the weight is reduced by approximately half. The additional items all have weights with the expected directions, i.e. indicators expected to be associated with higher SEP have positive weights and vice versa. Many of the additional items have fairly high weights, particularly sofa, coffee table, and mobile telephone.

Inclusion of additional assets in the wealth index resulted in a far smoother distribution of the index, with less clumping at lower values (**Figure 7.1**). The distribution was improved in all areas, but particularly in rural areas where clumping in the core wealth index is most severe.

Including additional assets in the wealth index resulted in a 24.0% lower difference in the observed wealth difference between urban and rural areas compared with the core index (**Table 7.2**). There were some small changes in the urban, peri-urban and rural composition of quintiles of the wealth index (**Table 7.3**), but the changes did not follow a consistent pattern; there was an increase in the proportion of households in both the top and bottom quintiles that were from rural areas.

Inclusion of additional assets in the wealth index had a fairly small impact on agreement of the wealth index with per capita consumption expenditure (**Table 7.4**). There is some evidence of an increase in agreement in rural areas; there is an absolute increase of 1.2% (relative increase of 4.6%) in the percentage of households classified in the same quintile by the wealth index and consumption expenditure, and a 24% relative increase in the Kappa statistic when additional assets are included in the index. There is, however, only a very small decrease in the proportion of rural households classified as lower by the wealth index than by consumption expenditure; 49.4% in the core index compared with 48.6% in the wealth index including additional assets, so an absolute decrease of 1.2% and a relative decrease of 1.6% (**Table 7.5**).

7.5.3 Inclusion of demographic and human capital variables

There are missing data for 0.68% of households and 1.4% of households for the wealth indices including the highest educational grade of the household head and including the full set of human capital and demographic indicators respectively. Levels of education and literacy are higher in urban areas than in rural areas, and there are also area differences in language spoken, age and sex of household head, and religion (**Appendix C**).

The proportion of the total variance explained by the first principal component is lower when highest educational grade of the household head is added to the core set of assets and lower still when further human capital and demographic variables are included (**Table 7.1C**). Many of the core assets have a lower weight when human capital and demographic variables are included in the wealth index. Having never attended school or having only partially completed primary school are assigned a negative weight, and the other achieved grades of education are assigned positive weights. In terms of achieved educational qualifications, having no qualification is assigned a negative weight, and all qualifications have a positive weight, with the weights for the highest two qualifications (MSCE and diploma or higher) being of similar magnitude.

Inclusion of highest educational grade of the household head resulted in a very small decrease (1.1%) in the difference in mean wealth index score between urban and rural areas. A slightly larger decrease (5.1%) was observed when the full set of human capital and demographic variables was included in the wealth index (**Table 7.2**).

Addition of highest educational grade of the household head resulted in little change to the distribution of the wealth index (**Figure 7.1C**). When the full set of human capital and demographic variables was added, however, the distribution of the wealth index was far smoother, with substantially less clumping (**Figure 7.1C**). The distribution was closer to a normal distribution in all areas, but the reduction in clumping was most marked in rural areas.

Inclusion of the full set of human capital and demographic variables in the wealth index resulted in a 10.6% relative increase in the proportion of households in the top quintile that were from rural areas (**Table 7.3**).

Although including the highest educational grade of the household head in the wealth index resulted in an increase in the Kappa statistic of agreement with consumption expenditure in all areas, there was little change in the proportion of households classified in the same quintile by the wealth index and consumption expenditure (**Table 7.4**). When the full set of human capital and demographic variables was included in the wealth index, there were further increases in the Kappa statistic in urban and peri-urban areas; in the whole population and in rural areas the Kappa statistics were similar to those for the wealth index including highest educational grade of the household head. However, there was little change in the proportion of households classified in the same quintile by the wealth index and consumption expenditure when comparing the core wealth index with the index including the full set of human capital and demographic variables. There was very little change in the proportion of households ranked higher or lower by the wealth index compared with consumption expenditure in either the whole population or in any area (**Table 7.5**).

A further wealth index was created which included both the demographic and human capital variables, and the additional consumer durables and service indicators. The inclusion of both of these sets of indicators did not result in further improvements in the distribution of the wealth index, nor in any improvement of agreement of the wealth index with consumption expenditure. This suggests that the improvement in distribution is largely a result of including a greater number of indicators in the index, but that above a certain number only limited further improvement is seen.

7.5.4 Inclusion of subjective measures of SEP

Missing data levels are low, and the index including all subjective SEP indicators has just 0.80% missing data. All indicators have strong urban-rural patterning, with urban areas displaying higher levels of perceived SEP (**Appendix C**).

The proportion of the total variance explained by the first principal component, which decreases with the inclusion of food consumption adequacy in the wealth index, and further decreases when the full range of subjective SEP indicators are included in the wealth index (**Table 7.1D**). The weights assigned to the indicators of subjective SEP are generally in the direction that would be anticipated. However, the weights for categories of the same question do not always follow a logical pattern, for instance 'more than adequate' is assigned a lower weight than 'just adequate' for questions relating to adequacy of food consumption, healthcare, housing and clothing (**Table 7.1D**).

The inclusion of a measure of subjective food consumption adequacy did little to alter the gap between mean wealth index scores in urban and rural areas, but the gap reduced by 18.1% when the full set of subjective SEP indicators were included in the wealth index (**Table 7.2**). This observation is supported by the fact that the top quintile of the wealth index including the full set of subjective SEP indicators contains eight percent more rural households than the wealth index containing only the core assets, a relative increase of 24.9% (**Table 7.3**).

Inclusion of the measure of food consumption adequacy does little to alter the distribution compared with the core assets index (**Figure 7.1D**). The wealth index including the full range of subjective SEP indicators, however, has markedly less clumping compared with the core assets index (**Figure 7.1D**). There remains some truncation at lower values in rural areas and to some extent in peri-urban areas.

Including the indicator of subjective food consumption expenditure adequacy has little effect on the agreement of the wealth index with consumption expenditure (**Table 7.4**). There is some indication that the proportion of urban households ranked higher by the wealth index than by consumption expenditure is lower when the full set of subjective SEP indicators is included in the wealth index, and that the proportion of rural households ranked lower by the wealth index is decreased (**Table 7.5**).

Table 7.1A: Weights assigned to indicators and proportion of variance explained by the first principal component in the wealth index including productive assets

Asset	*Wealth index using core assets*	*Wealth index including productive assets*
% variance explained by first principal component	*18.9*	*11.4*
Has electricity	0.3426	0.3472
Has radio	0.0194	0.0629
Has television/VCR	0.2835	0.3079
Has bicycle	0.0026	0.0882
Has motorbike/scooter	0.0432	0.0563
Has car	0.1887	0.2136
Has domestic servant	0.1425	0.1544
Owns agricultural land	-0.2279	-0.1023
Drinking water source		
Piped into dwelling	0.2762	0.3044
Piped outside dwelling	0.1630	0.1328
Communal standpipe	0.1250	0.0695
Personal handpipe/well	0.0154	0.0268
Communal handpipe/well	-.2269	-0.1371
River/spring/lake/reservoir/other	-.0433	-0.0396
Toilet facility		
Flush toilet	0.2760	0.2903
VIP latrine	0.0893	0.1098
Traditional latrine with roof	0.0014	-0.0012
Traditional latrine no roof	-0.0611	-0.0490
None or other	-0.0923	-0.0772
Material of dwelling floor		
Sand	-0.0078	0.0038
Smoothed mud/other	-0.3116	-0.2857
Smooth cement/wood/tiles	0.3313	0.3073
Cooking fuel		
Collected firewood	-0.3047	-0.2597
Purchased firewood	0.1251	0.1725
Paraffin/gas/charcoal	0.2194	0.1501
Electricity	0.2452	0.2585
Crop residue/sawdust/other	0.0042	0.0082
Sewing machine	-	0.1523
Ox-cart	-	0.0651
Wheelbarrow	-	0.1828
Hand-sprayer	-	0.0784
Cattle (number of)	-	0.0600
Chickens (number of)	-	0.0921
Other poultry (number of)	-	0.0576
Goats (number of)	-	0.0001
Sheep (number of)	-	0.0110
Pigs (number of)	-	-0.0033
Other livestock (number of)	-	0.0345
Area of land owned	-	-0.0250

Table 7.1B: Weights assigned to index items and proportion of total variance explained by the first principal component of the wealth index including additional items

Asset	*Wealth index using core assets*	*Wealth index including additional assets*
% variance explained by first principal component	*18.9*	*18.4*
Has electricity	0.3426	0.2419
Has radio	0.0194	0.0265
Has television/VCR	0.2835	0.2133
Has bicycle	0.0026	0.0300
Has motorbike/scooter	0.0432	0.0313
Has car	0.1887	0.1368
Has domestic servant	0.1425	0.1012
Owns agricultural land	-0.2279	-0.1191
Drinking water source		
Piped into dwelling	0.2762	0.1884
Piped outside dwelling	0.1630	0.1062
Communal standpipe	0.1250	0.0538
Personal handpipe/well	0.0154	0.0072
Communal handpipe/well	-0.2269	-0.1252
River/spring/lake/reservoir/ Other	-0.0433	-0.0327
Toilet facility		
Flush toilet	0.2760	0.1830
VIP latrine	0.0893	0.0553
Traditional latrine with roof	0.0014	0.0067
Traditional latrine no roof	-0.0611	-0.0398
None or other	-0.0923	-0.0681
Material of dwelling floor		
Sand	-0.0078	-0.0154
Smoothed mud/other	-0.3116	-0.1987
Smooth cement/wood/tiles	0.3313	0.2157
Cooking fuel		
Collected firewood	-0.3047	-0.1789
Purchased firewood	0.1251	0.0676
Paraffin/gas/charcoal	0.2194	0.1277
Electricity	0.2452	0.1703
Crop residue/sawdust/ Other	0.0042	-0.0061
Lighting fuel		
Collected wood/grass	-	-0.0406
Purchased wood		0.0065
Paraffin/diesel/gas		-0.1379
Electricity		0.2389
Batteries/candles/matches/ other		0.0342
Any household member sleeps under bed-net	-	0.1055
Bed	-	0.1702
Table	-	0.1293

Asset	*Wealth index using core assets*	*Wealth index including additional assets*
Chair	-	0.1123
Tape/CD player	-	0.1595
Fan	-	0.1966
Sewing machine	-	0.0734
Fridge	-	0.1985
Sofa	-	0.2164
Coffee table	-	0.2099
Cupboard	-	0.1856
Desk	-	0.0710
Clock	-	0.1808
Clothes iron	-	0.1688
Working landline telephone	-	0.1382
Working mobile phone	-	0.2034
Number of rooms	-	0.0705
Modern roof material	-	0.1956
Rubbish disposal facilities		
Collected from bin	-	0.1206
Rubbish pit		0.0316
Burning		-0.0188
Public rubbish heap		-0.0199
Other		-0.0187
None		-0.0510
Number of people per room	-	0.0314
Mortar and pestle	-	0.0053

Table 7.1C: Weights assigned to assets and proportion of the total variance explained by the first principal component of wealth indices including demographic and human capital variables

Asset	*Core assets*	*Including highest education grade of household head*	*Including human capital and demographic variables*
% variance explained by first principal component	*18.9*	*16.8*	*12.3*
Has electricity	0.3426	0.3274	0.2560
Has radio	0.0194	0.0239	0.0571
Has television/VCR	0.2835	0.2731	0.2126
Has bicycle	0.0026	0.0062	0.0312
Has motorbike/scooter	0.0432	0.0412	0.0319
Has car	0.1887	0.1801	0.1303
Has domestic servant	0.1425	0.1372	0.1043
Owns agricultural land	-0.2279	-0.2151	-0.1757
Drinking water source			
Piped into dwelling	0.2762	0.2675	0.1984
Piped outside dwelling	0.1630	0.1535	0.1269
Communal standpipe	0.1250	0.1133	0.0953
Personal handpipe/well	0.0154	0.0126	0.0106
Communal handpipe/well	-0.2269	-0.2097	-0.1643
River/spring/lake/reservoir/ Other	-0.0433	-0.0442	-0.0422
Toilet facility			
Flush toilet	0.2760	0.2653	0.1973
VIP latrine	0.0893	0.0842	0.0734
Traditional latrine with roof	0.0014	0.0040	0.0256
Traditional latrine no roof	-0.0611	-0.0580	-0.0477
None or other	-0.0923	-0.0921	-0.0978
Material of dwelling floor			
Sand	-0.0078	-0.0111	-0.0157
Smoothed mud/other	-0.3116	-0.2955	-0.2424
Smooth cement/wood/tiles	0.3313	0.3157	0.2618
Cooking fuel			
Collected firewood	-0.3047	-0.2882	-0.2365
Purchased firewood	0.1251	0.1171	0.1016
Paraffin/gas/charcoal	0.2194	0.2074	0.1760
Electricity	0.2452	0.2382	0.1765
Crop residue/sawdust/ other	0.0042	0.001	-0.0082
Highest educational grade of household dead			
None/pre-school only	-	-0.1032	-0.1595
Partial primary		-0.0983	-0.0966
Completed primary		0.0144	0.0538
Secondary		0.1751	0.2190
Higher education		0.1990	0.1616

Asset	*Core assets*	*Including highest education grade of household head*	*Including human capital and demographic variables*
Religion of household head			
None	-	-	-0.0423
Traditional			-0.0291
Islam			-0.0448
Catholic			0.0340
CCAP			0.0719
Other Christian			-0.0234
Marital status of household head			
Monogomous marriage	-	-	0.0886
Polygamous marriage			-0.0421
Divorced/separated			-0.0689
Widowed			-0.0667
Never married			0.0774
Language spoken at home			
Chichewa	-	-	0.0527
Nyanja			-0.0182
Yao			-0.0643
Tumbuku			0.0198
Other			-0.0226
Highest qualification of household head			
None	-	-	-0.2687
PSLC			0.0836
JCE			0.1337
MSCE			0.1647
Diploma or higher			0.1646
Female-headed household	-	-	-0.1029
Household age	-	-	-0.0986
Household head can read one page letter in Chichewa	-	-	0.1823
Household head can read one page letter in English	-	-	0.2403

Table 7.1D: Weights assigned to indicators in wealth indices including subjective measures of SEP

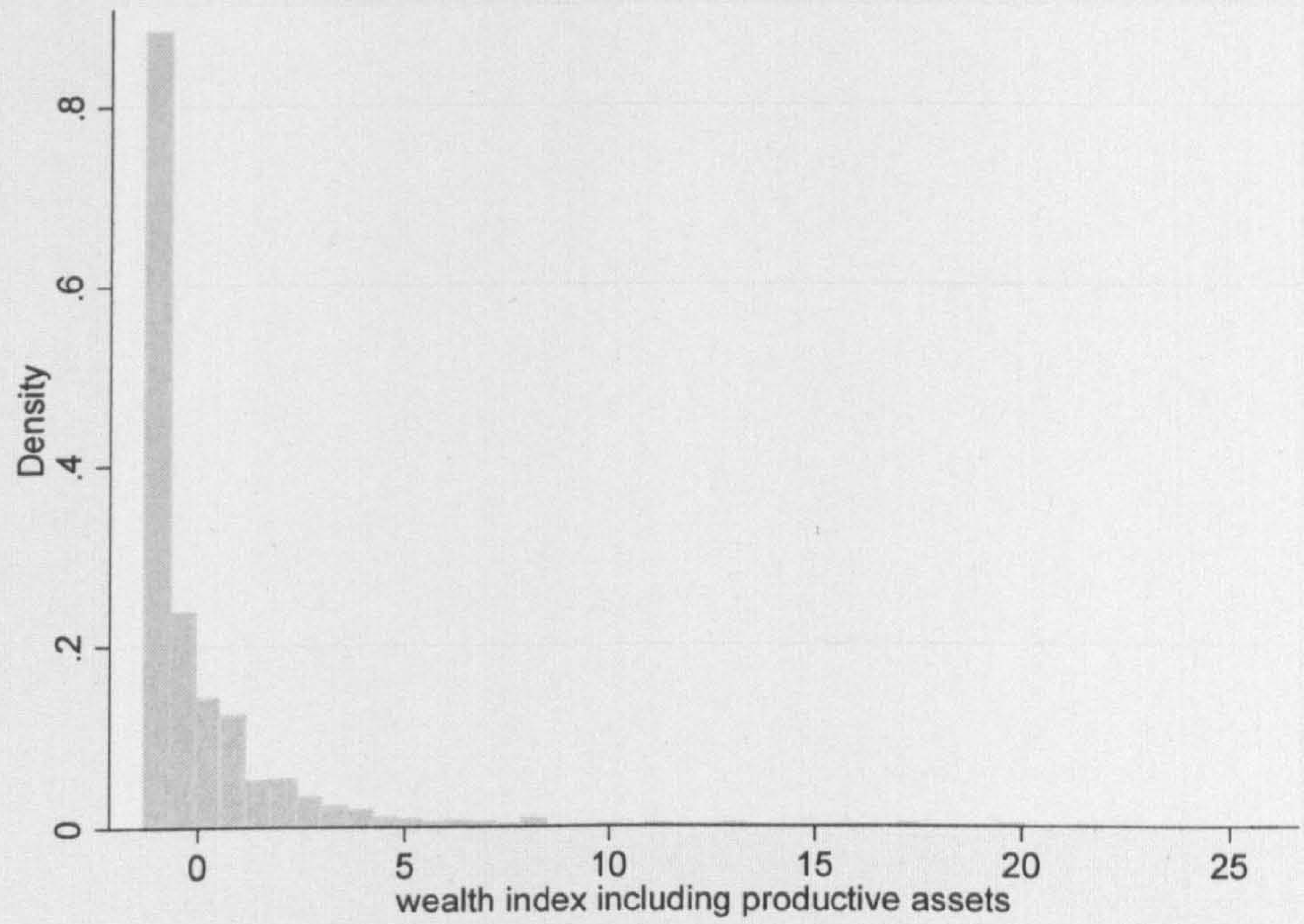
Variable	*Wealth index with core assets*	*Wealth index including adequacy of food consumption*	*Wealth index including full set of subjective SEP measures*
Percentage of total variance explained by 1st principal component	*18.9*	*17.4*	*12.9*
Electricity	0.3426	0.3366	0.2199
Radio	0.0194	0.0257	0.0570
Television/VCR	0.2835	0.2791	0.1877
Bike	0.0026	0.0093	0.0451
Motorbike	0.0432	0.0432	0.0344
Car	0.1887	0.1855	0.1193
Domestic servant	0.1425	0.1407	0.0940
Ownership of agricultural land	-0.2279	-0.2230	-0.1389
Drinking water source			
Piped into dwelling	0.2762	0.2703	0.1619
Piped outside dwelling	0.1630	0.1607	0.1111
Communal standpipe	0.1250	0.1207	0.0724
Personal handpump/well	0.0154	0.0146	0.0093
Communal handpump/well	-0.2269	-0.2202	-0.1308
River/spring/lake/reservoir/other	-0.0433	-0.0438	-0.0381
Toilet facility			
Flush toilet	0.2760	0.2694	0.1602
VIP latrine	0.0893	0.0883	0.0608
Traditional latrine with roof	0.0014	0.0074	0.0410
Latrine without roof	-0.0611	-0.0604	-0.0392
None or other	-0.0923	-0.0976	-0.1061
Floor material			
Sand	-0.0078	-0.0097	-0.0176
Smoothed mud	-0.3116	-0.3079	-0.2212
Smoothed cement/wood/tiles	0.3313	0.3282	0.2403
Cooking fuel			
Collect firewood	-0.3047	-0.3001	-0.2025
Buy firewood	0.1251	0.1247	0.0917
Paraffin/gas/charcoal	0.2194	0.2154	0.1477
Electricity	0.2452	0.2397	0.1436
Crop residue/saw dust/other	0.0042	0.0032	-0.0057
Adequacy of food consumption			
Less than adequate	-	-0.1304	-0.1787
Just adequate		0.1225	0.1440
More than adequate		0.0213	0.0739
Adequacy of housing			
Less than adequate	-	-	-0.1405
Just adequate			0.1143
More than adequate			0.0589
Adequacy of clothing			

Table 7.2: Mean scores of the wealth index including productive assets across types of area

	Mean score (standard error) in core wealth index	*Mean score (standard error) in wealth index including productive assets*	*Mean score (standard error) in wealth index including additional assets*	*Mean score (standard error) in wealth index including highest education grade of household head*	*Mean score (standard error) in wealth index including full set of human capital variables*	*Mean score (standard error) in wealth index including subjective food consumption adequacy*	*Mean score (standard error) in wealth index including full set of subjective SEP indicators*	*Mean (standard error) standardised consumption expenditure*
Whole population	-0.0153 (0.0254)	-0.0725 (0.0227)	-0.0645 (0.0241)	-0.0177 (0.0255)	-0.0356 (0.0235)	-0.0157 (0.0254)	-0.0496 (0.0223)	7.4×10^{-11} (0.0044)
Urban areas	1.544 (0.148)	1.523 (0.456)	1.269 (0.149)	1.523 (0.150)	1.443 (0.129)	1.522 (0.148)	1.220 (0.114)	0.8198 (0.0260)
Peri-urban areas	0.451 (0.118)	0.578 (0.157)	0.362 (0.109)	0.442 (0.118)	0.424 (0.119)	0.456 (0.117)	0.462 (0.110)	0.1841 (0.0145)
Rural areas	-0.304 (0.0157)	-0.170 (0.0162)	-0.135 (0.0131)	-0.304 (0.0153)	-0.311 (0.0156)	-0.301 (0.0158)	-0.294 (0.0165)	-0.1403 (0.00297)
Urban score – rural score	1.848	1.693	1.404	1.827	1.754	1.823	1.514	0.960

Variable	*Wealth index with core assets*	*Wealth index including adequacy of food consumption*	*Wealth index including full set of subjective SEP measures*
Less than adequate	-	-	-0.2080
Just adequate			0.1927
More than adequate			0.0631
Adequacy of healthcare			
Less than adequate	-.	-	-0.1355
Just adequate			0.1232
More than adequate			0.0384
Economic ladder question			
Step 1	-	-	-0.1795
Step 2			0.0409
Step 3			0.1398
Step 4 or above			0.1247
Income adequacy			
Allows you to build savings	-	-	0.1096
Allows you to save a little			0.0773
Just enough			0.0771
Not enough, use savings			0.0095
Not enough, must borrow			-0.1508
Life satisfaction			
Very unsatisfied	-	-	-0.0466
Unsatisfied			-0.0692
Neither unsatisfied nor satisfied			0.0419
Satisfied			0.0724
Very satisfied			0.0493
# Changes of clothes	-	-	0.2014
Sleeping place			
Bed and mattress	-	-	0.2423
Bed and mat			0.0178
Bed alone			0.0109
Mattress on floor			0.0198
Mat (grass) on floor			-0.2115
Floor/cloth/other			-0.0322
Sleeping in cold season			
Blanket and sheet	-	-	0.2149
Blanket alone			-0.1267
Sheet alone			-0.0191
Cloth/clothes/nothing			-0.0896

Figure 7.1A: Distribution of the wealth index including productive assets



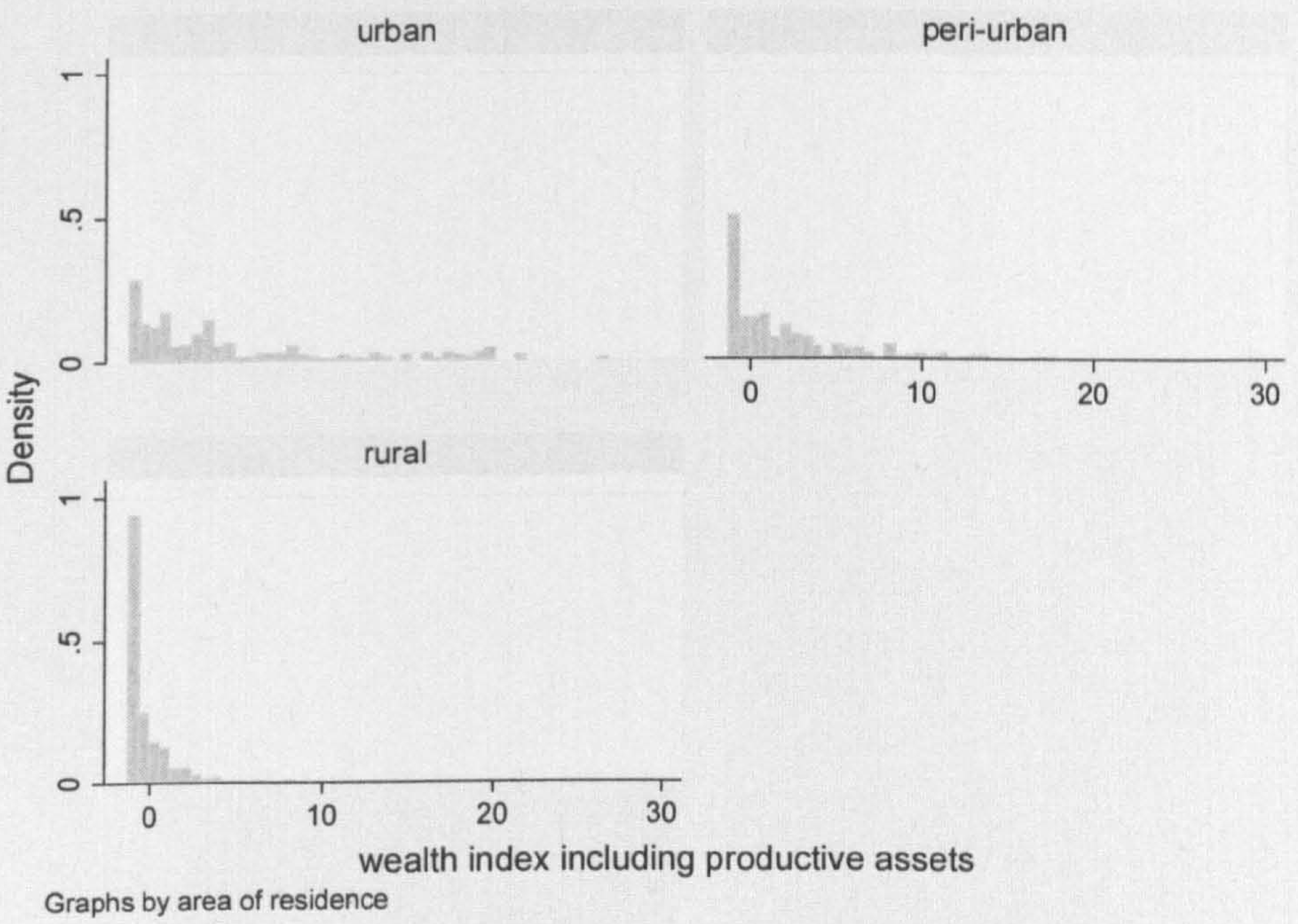
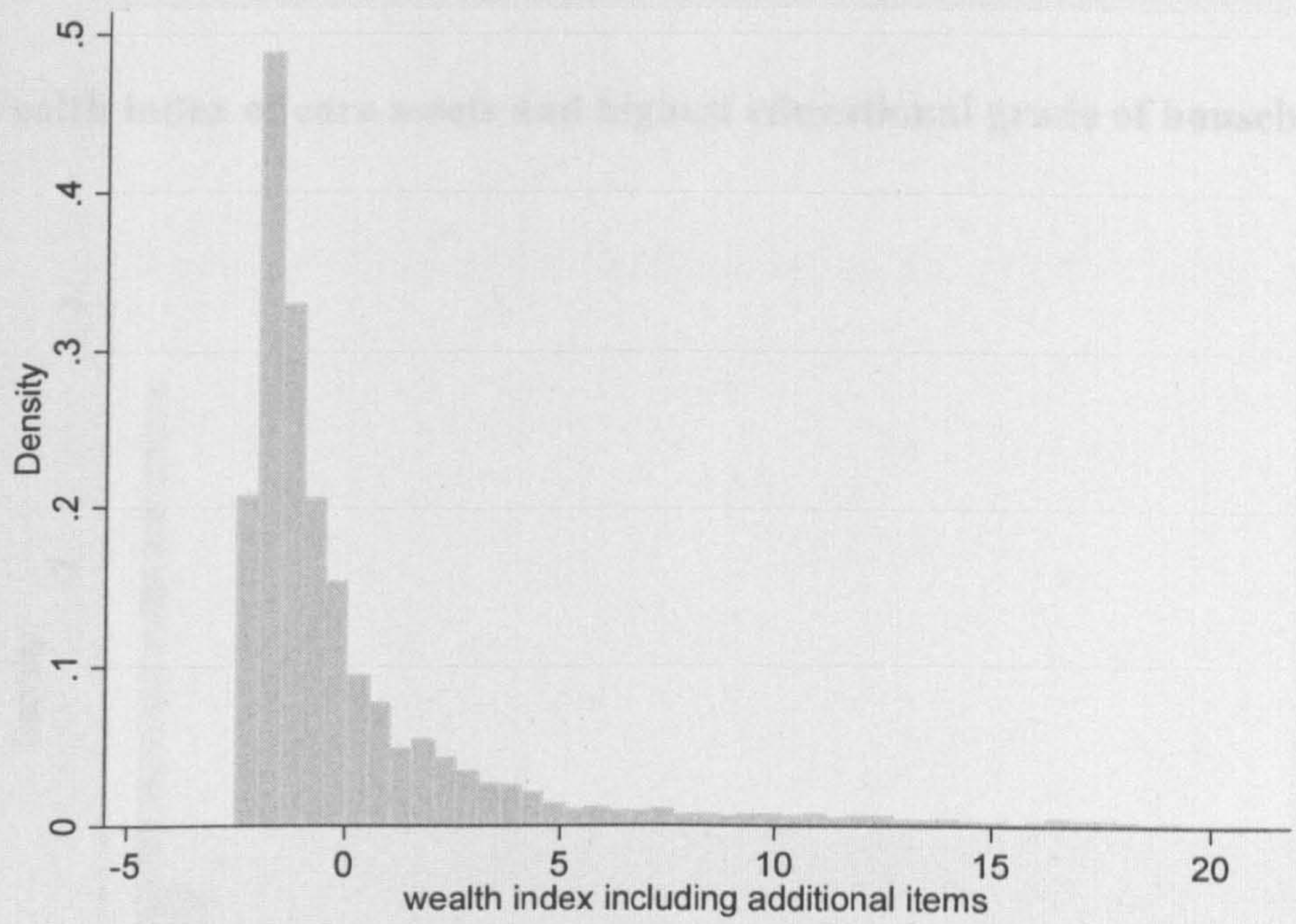


Figure 7.1B: Distribution of the wealth index including additional assets



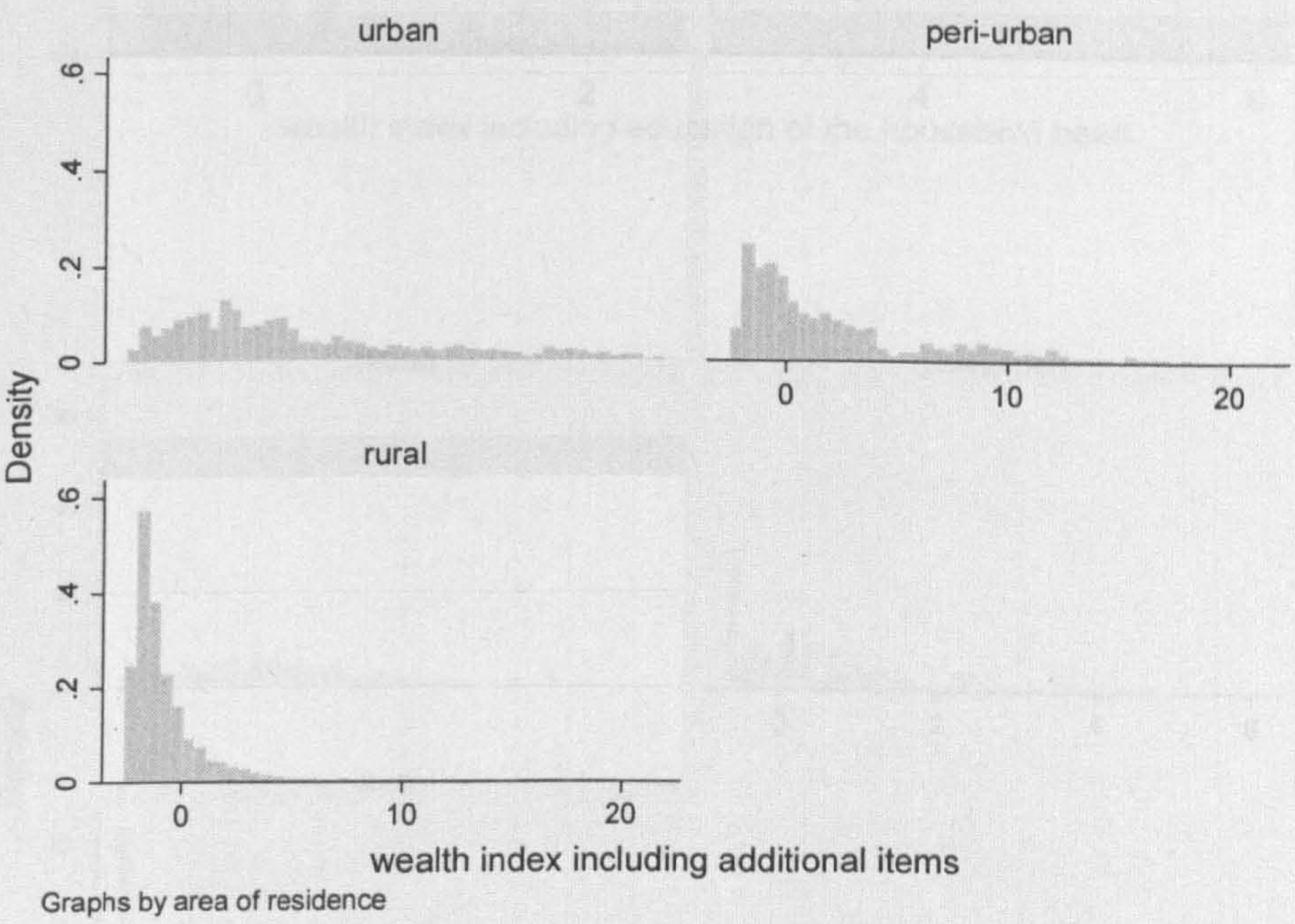
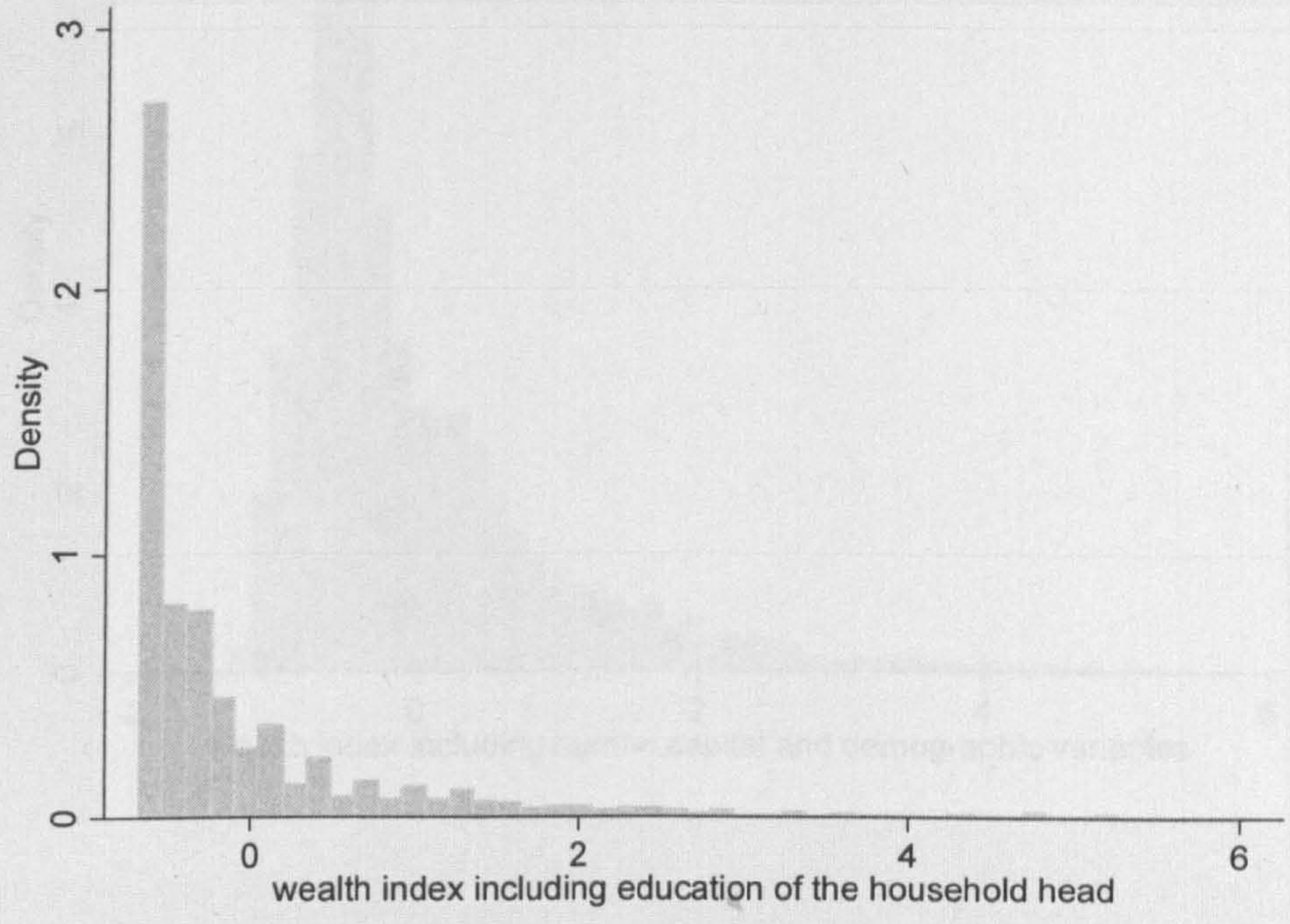
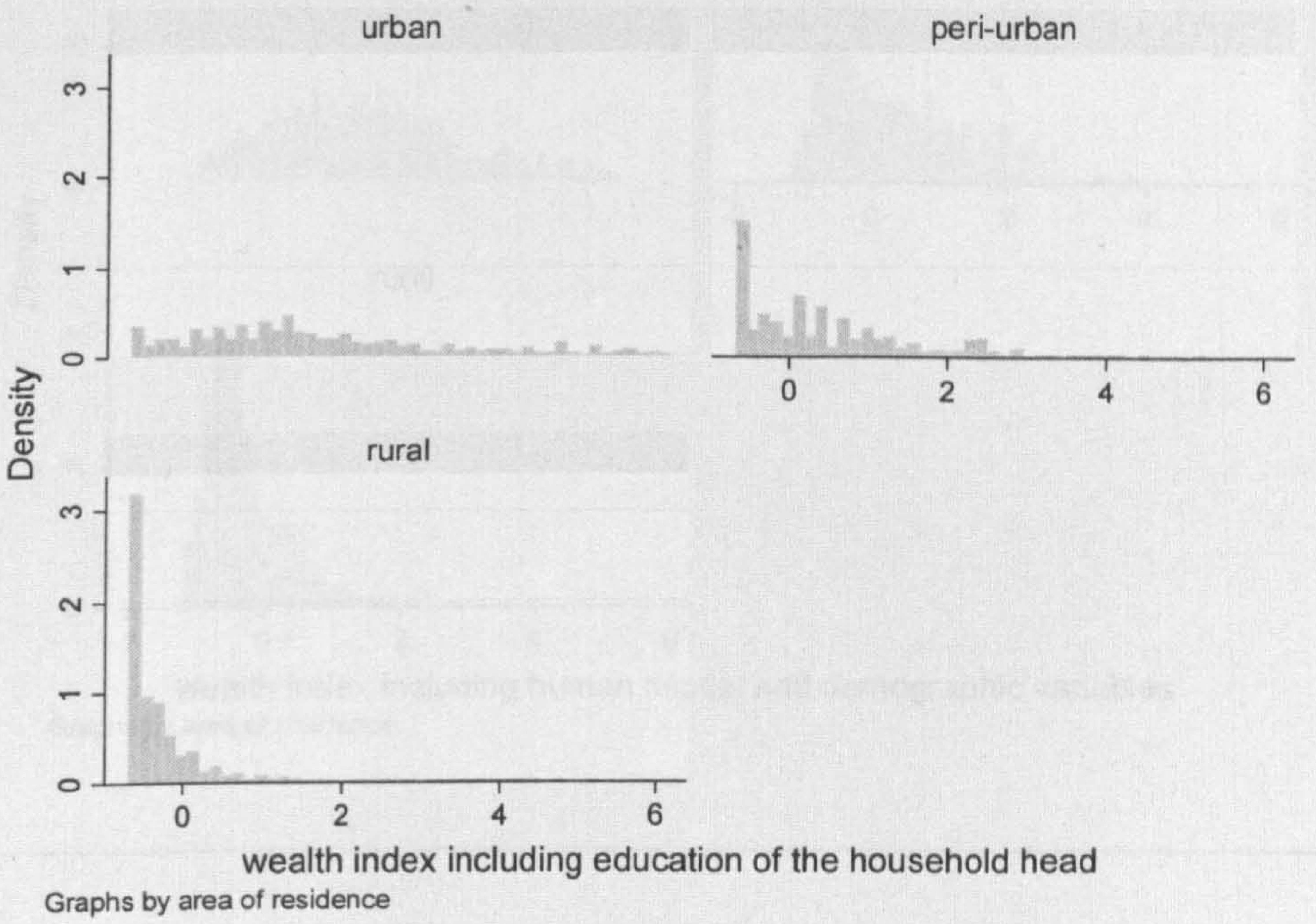


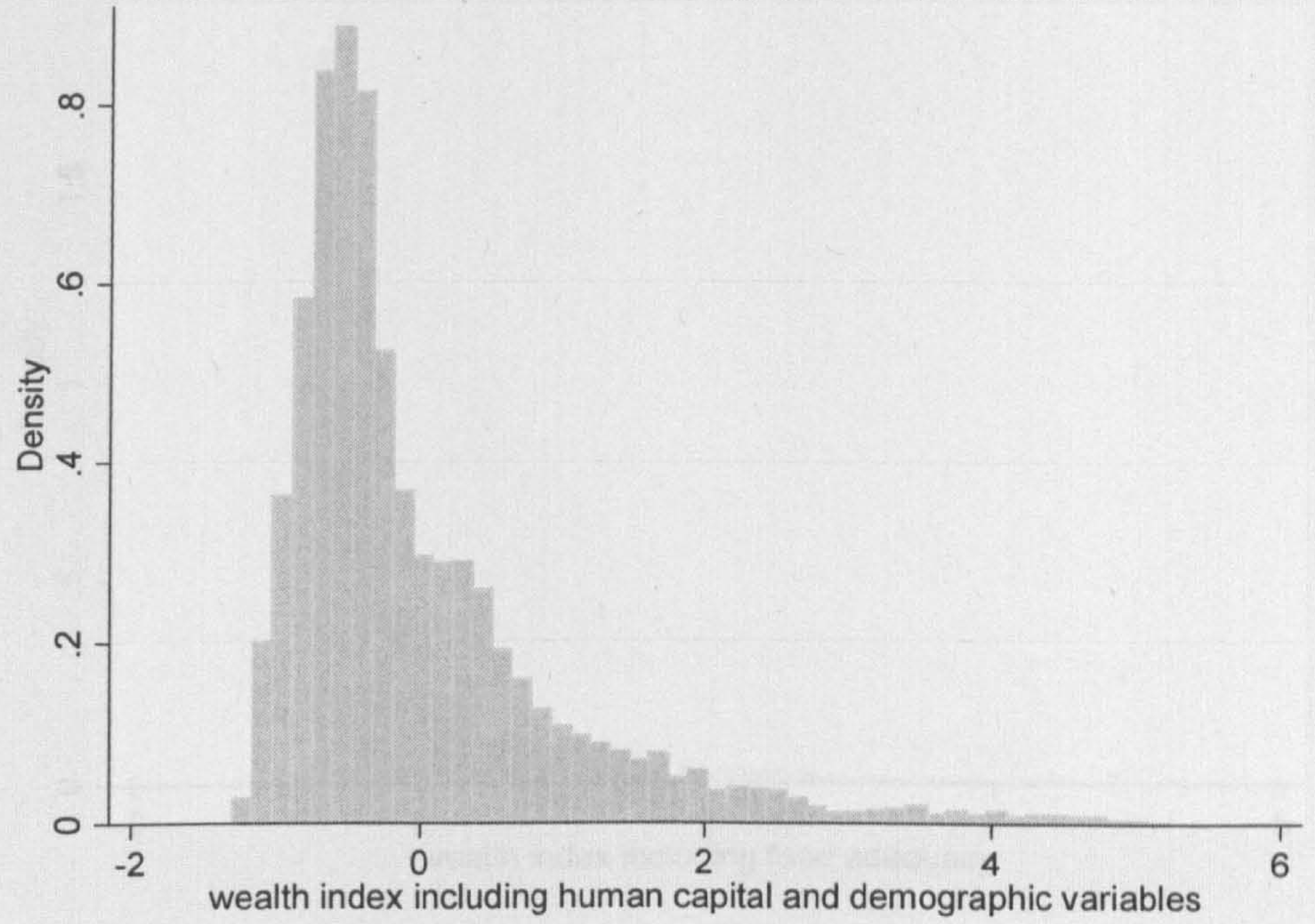
Figure 7.1C: Distribution of the wealth indices including demographic and human capital variables

Wealth index of core assets and highest educational grade of household head





Wealth index of core assets and full set of human capital and demographic variables



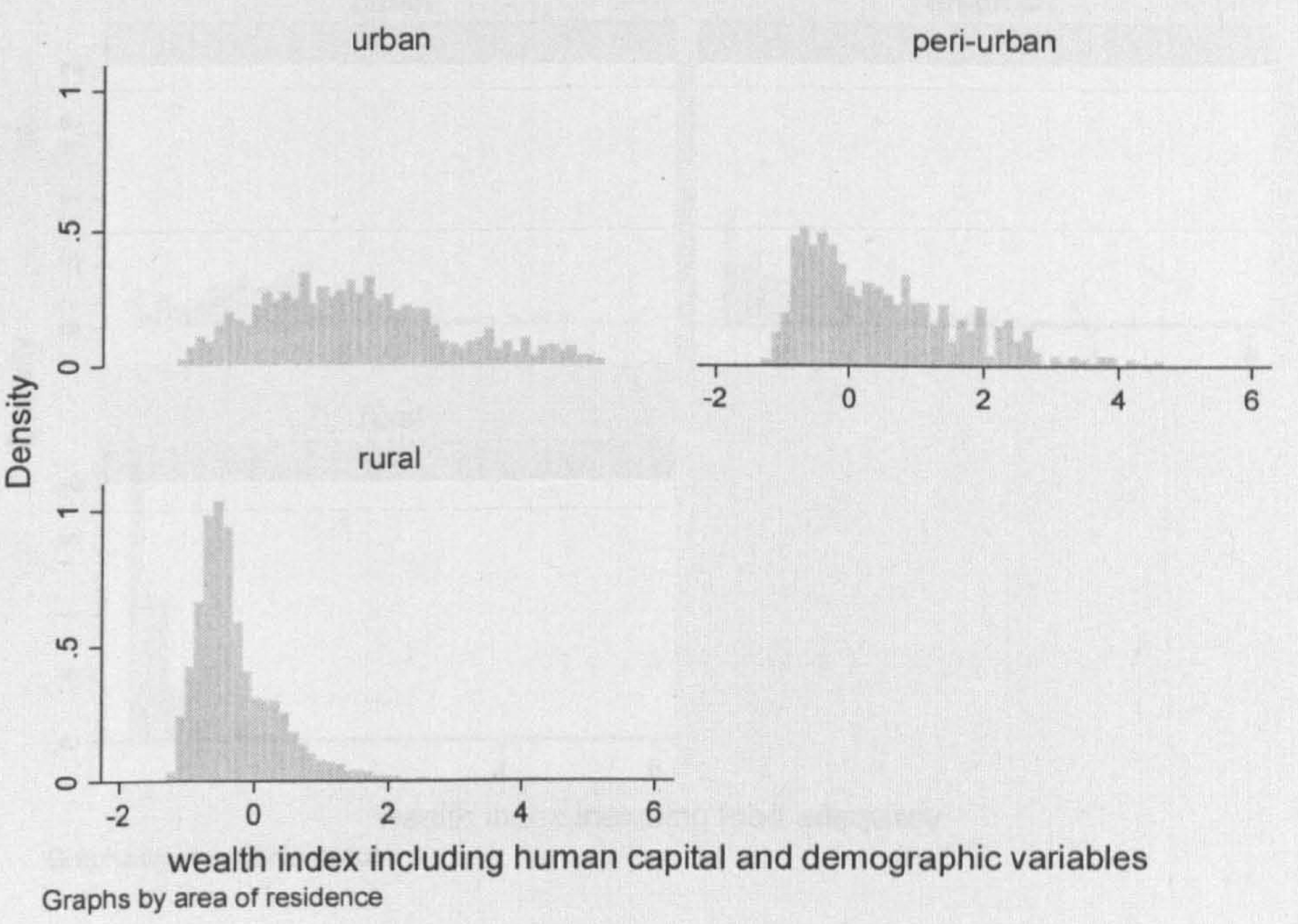
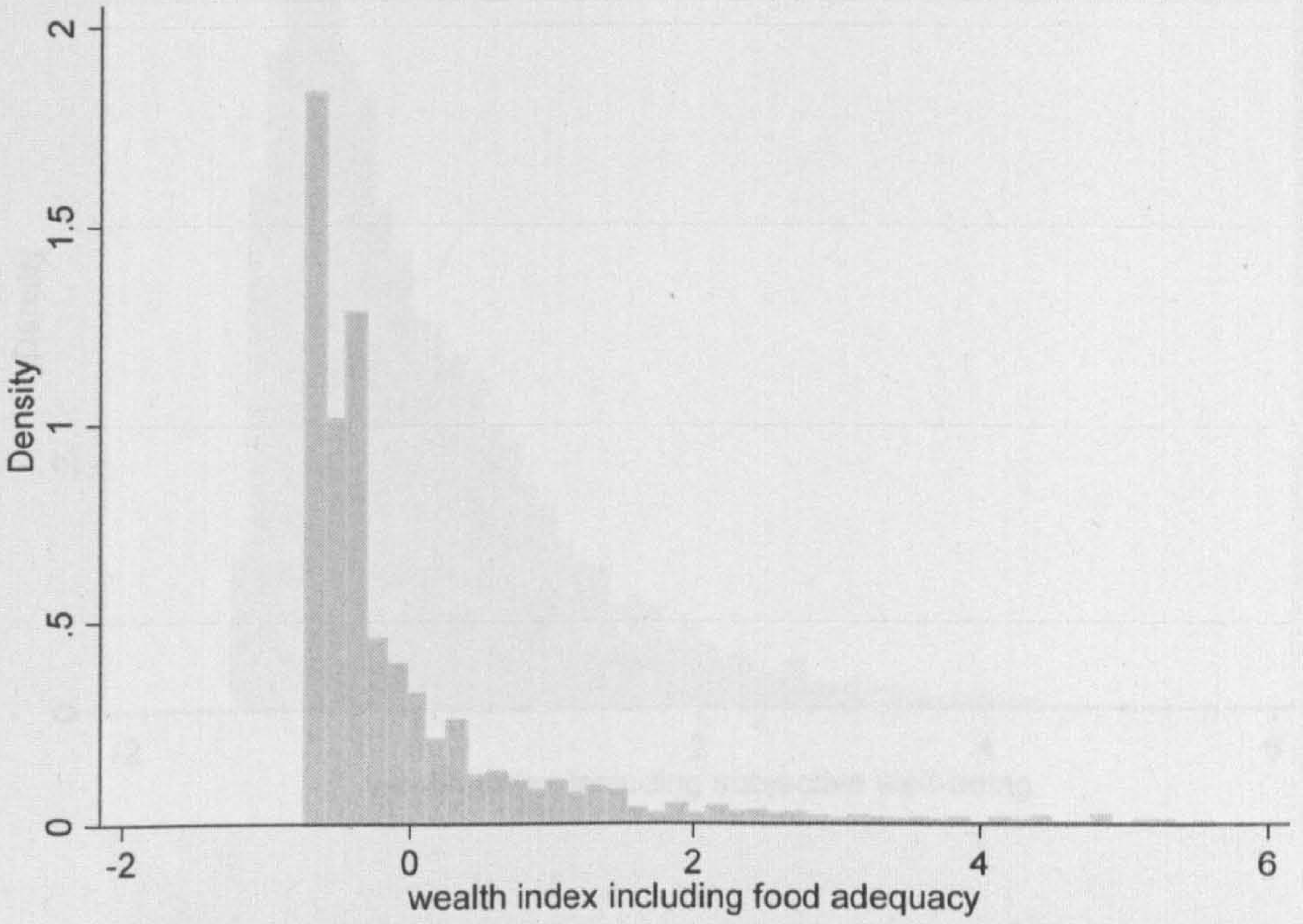
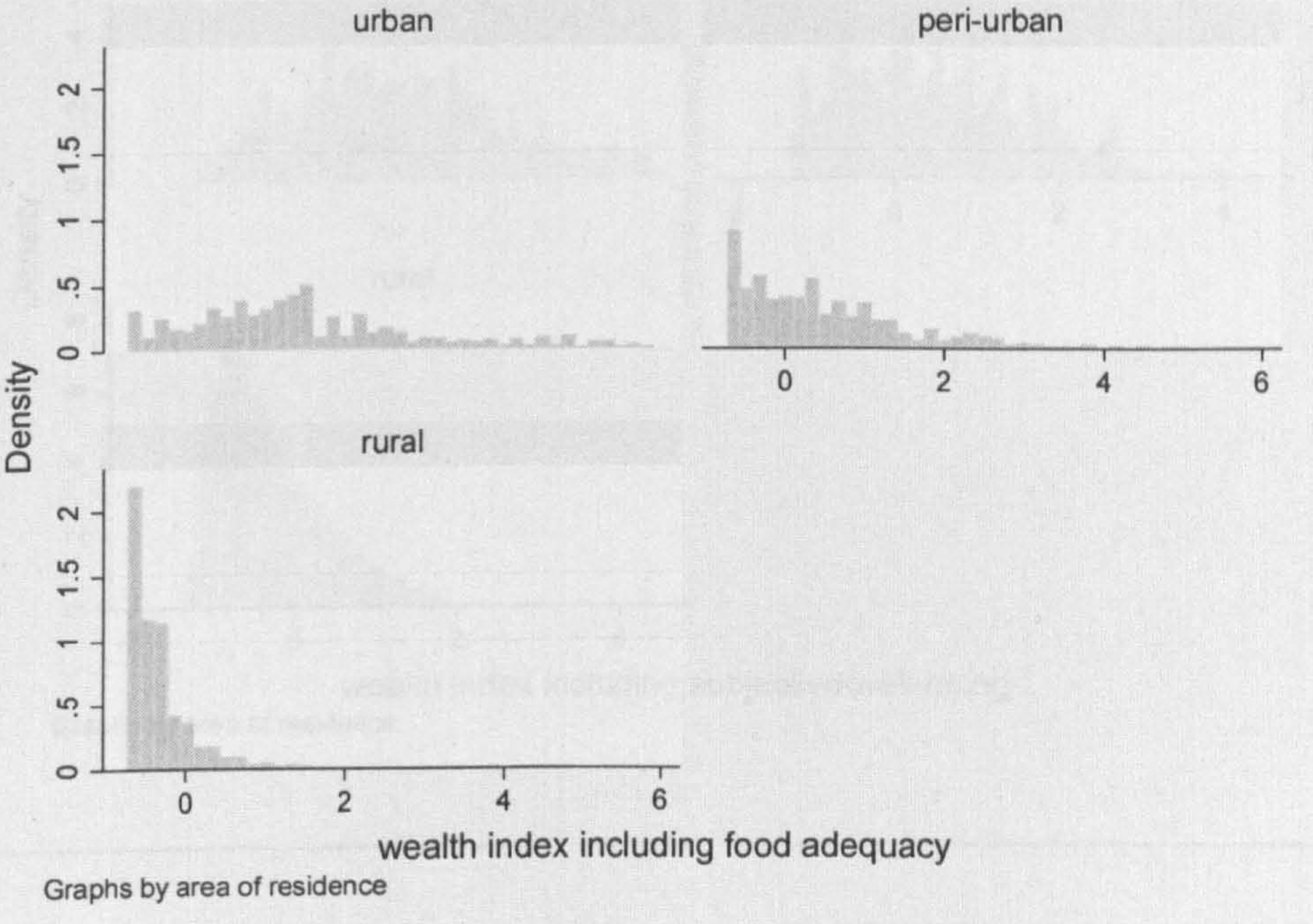


Figure 7.1D: Distribution of wealth indices including measures of subjective SEP

Wealth index including core assets and a measure of food consumption adequacy





Wealth index including core assets and the full set of subjective SEP indicators

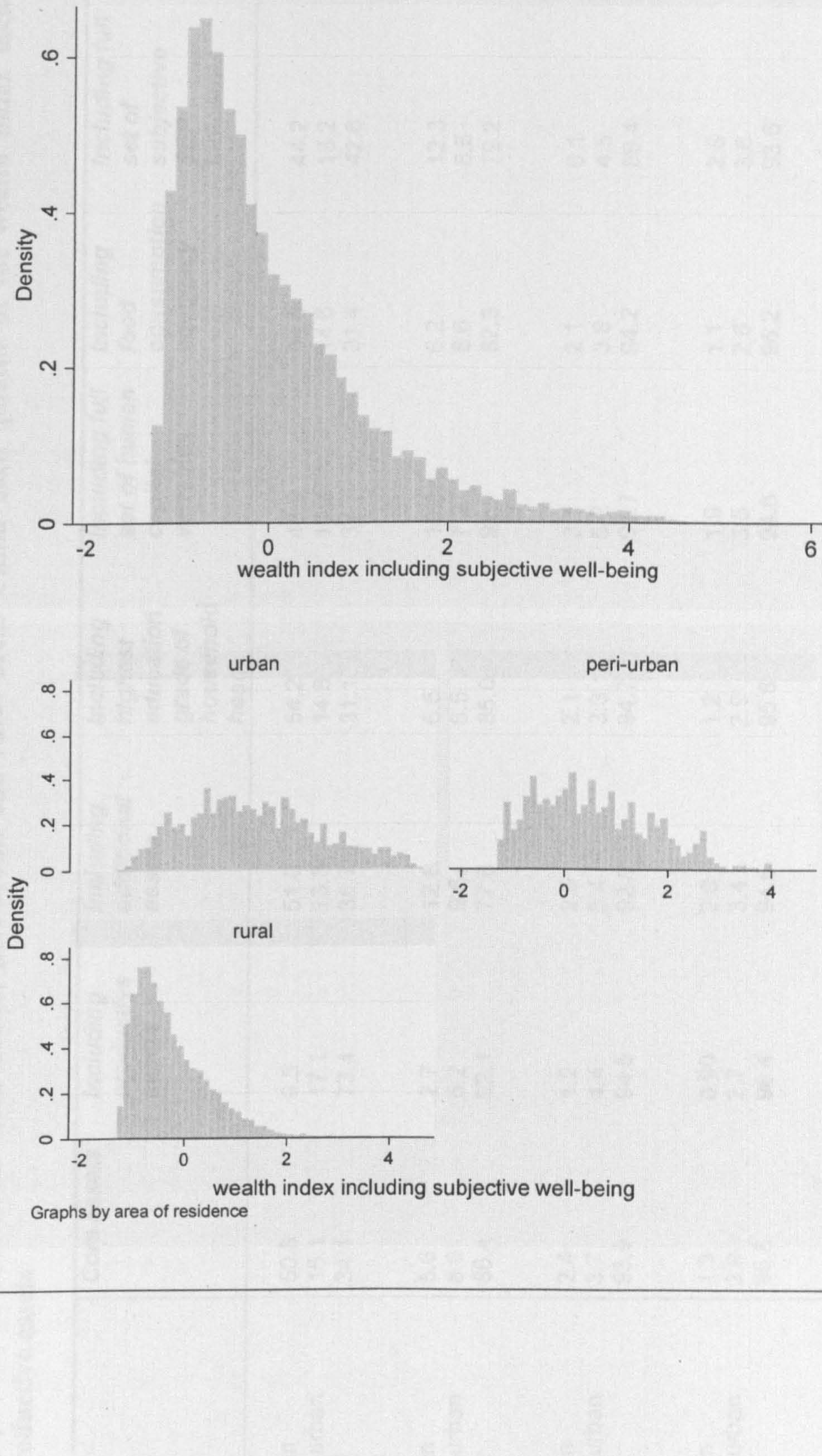


Table 7.3: Proportion of households from urban, peri-urban and rural areas within each quintile of the wealth index including productive assets

	Core assets	*Including productive assets*	*Including additional assets*	*Including highest education grade of household head*	*Including full set of human capital variables*	*Including food consumption adequacy*	*Including full set of subjective SEP indicators*
Top quintile							
proportion urban	50.8	9.5	51.0	54.2	48.9	54.0	44.2
proportion peri-urban	15.1	17.1	13.3	14.8	13.4	14.6	13.2
proportion rural	34.1	73.4	35.7	31.1	37.7	31.4	42.6
Quintile 4							
proportion urban	5.6	2.7	12.8	6.5	10.1	6.2	12.3
proportion peri-urban	8.0	5.2	9.6	8.5	7.2	8.6	8.5
proportion rural	86.4	92.1	77.6	85.0	92.7	82.3	79.2
Quintile 3							
proportion urban	2.4	1.2	2.6	2.1	3.1	2.1	6.1
proportion peri-urban	3.7	4.4	5.4	3.3	5.2	3.8	4.5
proportion rural	93.9	94.5	92.0	94.7	91.7	94.2	89.4
Quintile 2							
proportion urban	1.3	0.90	2.0	1.2	1.9	1.1	2.8
proportion peri-urban	2.9	2.7	3.4	2.9	3.5	2.6	3.6
proportion rural	95.8	96.4	94.6	95.8	94.6	96.2	93.6
Bottom quintile							
proportion urban	2.3	1.7	2.0	2.2	2.1	2.4	1.2
proportion peri-urban	4.1	4.0	2.6	3.7	3.9	3.4	3.3
proportion rural	93.6	94.3	95.4	94.1	93.9	94.2	95.6

Table 7.4: Agreement between classification into quintiles of per capita consumption expenditure and the wealth index including productive assets

	% Households moving between quintiles of wealth index and per capita consumption expenditure					
Index	*Same quintile*	*Move 1 quintiles*	*Move 2 quintiles*	*Move 3 quintiles*	*Move 4 quintiles*	*Kappa (SE)*
Core assets						
Whole population (n=11243)	28.9	33.5	20.4	13.6	3.6	*0.11 (0.005)*
urban areas (n=1434)	54.7	24.0	12.7	6.6	2.1	*0.16 (0.01)*
peri-urban areas (n=739)	37.5	35.4	14.7	10.7	1.8	*0.13 (0.02)*
rural areas (n=9070)	24.1	34.9	22.1	15.0	4.0	*0.05 (0.005)*
Including productive assets						
Whole population (n=7057)	26.6	34.1	23.2	12.5	3.6	*0.073 (0.006)*
urban areas (n=257)	47.1	28.1	16.6	6.4	1.8	*0.18 (0.03)*
peri-urban areas (n=431)	35.0	32.9	18.9	11.3	2.0	*0.14 (0.02)*
rural areas (n=6369)	25.3	34.6	23.7	12.8	3.8	*0.055 (0.006)*
Including additional assets						
Whole population (n=11182)	29.6	35.3	21.2	10.4	3.5	*0.11 (0.005)*
urban areas (n=1430)	53.9	27.8	11.8	5.1	1.4	*0.16 (0.01)*
peri-urban areas (n=736)	35.7	38.3	17.0	7.2	1.9	*0.13 (0.02)*
rural areas (n=9016)	25.2	36.3	23.1	11.5	3.9	*0.062 (0.005)*
Including highest education grade of household head						
Whole population (n=11203)	29.8	34.0	21.3	11.5	3.5	*0.12 (0.005)*
urban areas (n=1430)	54.9	24.1	12.8	6.5	1.7	*0.17 (0.01)*
peri-urban areas (n=737)	38.8	34.1	16.3	8.5	2.3	*0.15 (0.02)*
rural areas (n=9036)	25.0	35.6	23.1	12.5	3.8	*0.062 (0.005)*
Including full set of human capital variables						
Whole population (n=11153)	30.3	34.5	20.9	10.5	3.9	*0.13 (0.005)*
urban areas (n=1423)	54.8	26.1	12.0	5.8	1.3	*0.20 (0.02)*
peri-urban areas (n=733)	40.6	33.5	15.6	7.6	2.7	*0.20 (0.02)*
rural areas (n=8997)	25.5	35.9	22.8	11.5	4.4	*0.069 (0.005)*
Including subjective food consumption adequacy						
Whole population (n=11203)	29.8	34.8	21.3	11.0	3.1	*0.12 (0.005)*
urban areas (n=1430)	55.1	24.2	12.8	6.2	1.8	*0.16 (0.01)*
peri-urban areas (n=737)	39.1	34.0	17.0	8.3	1.7	*0.15 (0.02)*
rural areas (n=9036)	25.0	36.5	23.0	12.0	3.5	*0.060 (0.005)*
Including full set of subjective SEP indicators						
Whole population (n=11153)	31.2	36.2	20.4	9.6	2.7	*0.13 (0.005)*
urban areas (n=1423)	53.1	30.2	12.4	3.5	0.85	*0.22 (0.02)*
peri-urban areas (n=733)	39.3	35.1	17.1	6.9	1.6	*0.17 (0.02)*
rural areas (n=8997)	27.0	37.2	21.9	10.8	3.1	*0.085 (0.005)*

Table 7.5: Increased, decreased or unchanged ranking of households between quintiles of per capita consumption expenditure and the wealth index including productive assets

Index	*Lower quintile by wealth index*	*Same quintile*	*Higher quintile by wealth index*
Core assets			
Whole population (n=11243)	42.6	28.9	28.4
urban areas (n=1434)	7.6	55.0	37.4
peri-urban areas (n=739)	28.8	37.4	33.8
rural areas (n=9070)	49.4	24.1	26.5
Including productive assets			
Whole population (n=7057)	26.5	16.2	57.3
urban areas (n=257)	2.6	6.6	90.8
peri-urban areas (n=431)	17.0	20.6	62.3
rural areas (n=6369)	31.1	17.4	51.5
Including additional assets			
Whole population (n=11182)	42.8	29.4	27.9
urban areas (n=1430)	11.9	53.5	34.6
peri-urban areas (n=736)	31.8	35.5	32.7
rural areas (n=9016)	48.6	25.0	26.4
Including highest educational grade of household head			
Whole population (n=11203)	41.4	29.6	29.0
urban areas (n=1430)	7.4	54.6	38.0
peri-urban areas (n=737)	28.5	38.7	32.9
rural areas (n=9036)	47.9	24.9	27.2
Including full set of human capital variables			
Whole population (n=11153)	41.2	29.9	28.9
urban areas (n=1423)	10.4	54.2	35.5
peri-urban areas (n=733)	30.6	40.2	29.2
rural areas (n=8997)	47.0	25.2	27.8
Including subjective food consumption adequacy			
Whole population (n=11203)	41.4	29.7	28.9
urban areas (n=1430)	7.5	54.8	37.8
peri-urban areas (n=737)	27.7	38.9	33.4
rural areas (n=9036)	48.0	24.9	27.1
Including full set of subjective SEP indicators			
Whole population (n=11153)	40.5	30.9	28.6
urban areas (n=1423)	14.4	52.3	33.3
peri-urban areas (n=733)	29.7	39.0	31.3
rural areas (n=8997)	45.6	26.8	27.6

7.6 Discussion

The approaches to wealth index construction explored in this chapter had some effects on the wealth index distribution, and urban-rural patterns of the wealth index. Generally, however, there was minimal impact on the agreement of the wealth index with consumption expenditure. Each approach that involved a substantial increase in the number of indicators resulted in a smoother wealth index distribution, with less clumping overall and particularly in rural areas. For several approaches, the extent of clumping of wealth index scores in rural areas was reduced to a similar extent observed in the consumption expenditure distribution (see **Figure 2.1**). Most of the approaches also resulted in a decrease in the observed difference in mean wealth index scores between urban and rural areas, although the difference between urban and rural areas always remained greater than the difference in consumption expenditure. Also, this did not always translate to a decrease in the proportion of rural households ranked in a lower quintile by the wealth index than by consumption expenditure. The reason for the decreased clumping in wealth index distribution is probably the increased number of indicators, rather than any specific features of the indicators included. Increasing the number of indicators leads to additional variation between the households, which assists in separating out the households and generating evenly-sized quintiles. The addition of these extra indicators does not increase the ability of the wealth index to act as a proxy for consumption expenditure, and as such as have no benchmark against which to judge whether or not the expanded wealth indices are 'better' measures of SEP than the core wealth index, other than to say that increasing the number of indicators results in a less clumped distribution. In terms of generating a measure that can successfully differentiate between households in a population, and in particular in a rural population, it would seem appropriate to use a greater number of indictors than the core set used by the DHS whenever possible.

Other than the recommendation that the number of indicators used in a wealth index should generally be higher than in the DHS wealth indices, my recommendation would be to choose indicators based on locally-relevant and theoretical grounds. If formative research or local knowledge suggests that certain items are highly indicative of SEP in a particular setting, it makes sense to include those in a wealth index. Furthermore, if there is a belief that, for instance, productive assets are a key aspect of SEP particularly relevant for the health outcome of interest, it may be sensible to include those in a wealth index. If, however, there is a specific interest in a type of variable and its relationship with the outcome, these indicators should probably be used as a separate variable rather than including them in the wealth index.

The findings presented here may not be transferable to other settings, and further work exploring the impact of indicator choice is recommended in other datasets. A further continuation of this work could be to explore the relationship of the wealth indices with and without subjective SEP indicators with other measures of SEP in order to test whether the approach results in a wider concept of SEP being captured by the wealth index.

7.7 Chapter key messages

1. Increasing the number of indicators in a wealth index results in a less clumped distribution
2. Including productive assets, additional consumer durables and service indicators, human capital and demographic indicators, or subjective SEP indicators can reduce the observed gap in wealth index scores between urban and rural households
3. Broadening the types of indicator used to construct a wealth index has little effect on its agreement with consumption expenditure
4. Indicator choice should be based on local relevance and theory of the important aspects of SEP and how these relate to the outcome of interest

7.8 Next steps

This chapter concludes the exploration of the second research question about whether the methods of wealth index construction used by the DHS are the most appropriate.

In the next section, I go on to address the third and final research question: what are the consequences of using the wealth index? In **Chapter 8**, I explore the important question of what the wealth index is measuring. I investigate the socio-economic processes that contribute to a household's position in the wealth index hierarchy, by modelling the relationship of the wealth index with other SEP indicators.

Part IV: What socio-economic processes contribute to the wealth index hierarchy?

8. What does a wealth index measure?

In this section of the thesis, I address my third research question: what socio-economic processes contribute to a wealth index hierarchy?

This chapter attempts to improve the understanding and interpretation of health inequalities observed when using the wealth index as a measure of SEP, through exploring the socio-economic determinants of a household's position within the wealth index hierarchy. There is a lack of clarity in the conceptual meaning of the wealth index. The evidence presented in previous chapters of this thesis suggests that the ability of a wealth index to proxy consumption expenditure is variable, but generally tends to be weak. The social stratification processes leading to a household's position in the wealth index hierarchy are therefore uncertain. This leads to difficulty in drawing clear and useful interpretations and policy implications from inequalities demonstrated using a wealth index. This chapter attempts to shed some light on the social processes being captured by the wealth index, by modelling the relationships between the wealth index and its proposed socio-economic determinants.

8.1 Chapter objective

The overall chapter objective is:

- To explore the socio-economic determinants of the wealth index

Specific objectives are detailed after a review of the main issues and concerns presented below.

8.2 Background

Although social epidemiology must first seek to describe and understand the nature of social processes and how they affect health, the ultimate aim must be to address the social problems leading to inequalities.[23] For social epidemiology to be turned into effective pro-equality policy, the causes rather than simply the correlates of social problems must be understood.[23] Thus socio-economic position indicators should be exposures with clearly hypothesised causal pathways to health and clear policy implications. This is arguably far from the case with the wealth index.

The indicators used to construct a wealth index are clearly a reflection of certain aspects of living standards. The nature of the social stratification processes leading to a household's wealth index ranking remains, however, unclear. I view wealth index rankings as the outcome of social processes that also determine other SEP indicators. In this sense, the wealth index is viewed as a more 'proximal' SEP indicator than other measures such as education and consumption expenditure. For simplicity, the socio-economic factors hypothesised to be contributing to wealth index rankings will be referred to as 'the determinants of the wealth index'.

Despite the widespread use of wealth indices in epidemiological research, the concept of SEP being measured by a wealth index remains uncertain. The vast majority of researchers provide no theoretical justification for using the wealth index as a measure of SEP, or any suggested explanation for its relationship with health. Those who do justify the use of the wealth index tend to propose the wealth index as a proxy for consumption expenditure.[58] The systematic review presented in **Chapter 2** demonstrated that in most cases this is an unreasonable assumption, but little is known about which socio-economic processes are giving rise to wealth index hierarchies. This lack of theoretical grounding makes the interpretation of research findings and their policy implications uncertain.

There is some concern that wealth index rankings are driven more by area of residence than by household-level factors, and that the wealth index represents an unhelpful mixing of household and community effects.[243] The consumer durables included in a 'standard' wealth index have an urban bias; they are likely to be more widely available in urban areas compared with rural areas for reasons other than household SEP. The housing characteristic indicators also have an urban bias, with traditional materials generally being given a lower weight in PCA than modern materials. This means that a wealthy rural household living in a traditional-style house could be assigned a lower SEP score than a poor urban household living in housing constructed from modern materials. Indicators of access to public services have a stronger-still urban bias. Services such as electricity, drinking water, and sanitation facilities are primarily provided at the community-level. There are, therefore, considerable grounds for concern that a wealth index is mixing household and community-level effects. If this is the case, the policy implications of inequalities in a wealth index are uncertain – should policies be directed at raising household SEP (in terms of income, education, or otherwise), or by improving facilities and services at an area-level? Although area is likely to be an important determinant of all aspects of SEP, its influence may be stronger for the wealth index than for other SEP indicators. For instance, I demonstrated in **Chapter 6** that a wealth index tends to rank urban households as higher than consumption expenditure, and vice versa for rural households, i.e. there is a bigger urban-rural SEP gap by the wealth index compared with by consumption expenditure.

8.3 Objectives

In addition to the overall chapter objective, specific objectives are to:

1. Explore the socio-economic processes giving rise to wealth index rankings
2. Compare the importance of household- and community-level determinants of the wealth index
3. Examine whether and how the strength of determinants of the wealth index differs between urban, peri-urban, and rural areas

8.4 Hypotheses

i) All available household- and community-level socio-economic indicators will be associated with the wealth index

ii) The wealth index will be strongly determined by community-level factors. These factors will be as or more important than household-level SEP indicators in determining the wealth index

iii) Consumption expenditure and education of the household head will be stronger determinants of the wealth index in urban areas compared with peri-urban and rural areas. Community infrastructure may be a more important determinant of the wealth index in rural areas compared with urban and peri-urban areas.

8.5 Methods

8.5.1 Path analysis

Path analysis is an extension of multiple regression models. It is a methodology for examining complex relationships between sets of variables, and is capable of answering more intricate questions than standard regression techniques can handle.[313] A path model starts with a model setting out hypothesised relationships between variables, and tests the extent to which this theoretically-derived model is supported by the observed data. It is thus designed primarily for theory testing rather than theory generation. Model fit can be assessed, and if necessary models can be refined and re-tested.

Multiple dependent variables can be included in path models, such that hypothesised inter-relationships between a large set of variables can be mapped out and tested. This allows more complex models to be tested than multiple regression can deal with. Although similar questions can be answered using sequential multiple regressions, hypothesised relationships can be more explicitly laid out and tested using path models. A further advantage is that path models allow the estimation of both direct and indirect effects.[314]

Path analysis is an appropriate technique to answer the research questions in this section because it will allow the complex interplay between the wealth index and other socioeconomic indicators to be mapped out and tested. The roles of other socioeconomic indicators, urban/rural area and community infrastructure can be examined in order to assess whether concerns that the wealth index is primarily driven by urban/rural area and community infrastructure are justified. All of the indicators hypothesised to be determinants of the wealth index are inter-related, and such complex inter-relationships could not be modelled using standard regression techniques. Path analysis will also enable the direct and indirect effects to be estimated; for example area of residence is likely to act both directly on the wealth index, and through other SEP indicators such as consumption expenditure. A further benefit of fitting a single path model rather than a series of standard regression models is that global model fit can be assessed, i.e. the observed covariance matrix can be compared with the matrix estimated by the model.

The steps in path analysis are:(chapter 1, pages1-12)[314]

1. *Specification*
   Deciding, based on theory and previous research, which variables to include in the model, and how they are hypothesised to be inter-related
2. *Identification*
   An identified model is one where a unique set of parameter estimates can be found, given the observed variance-covariance matrix
3. *Estimation*
   Model parameters are estimated using the appropriate estimation method for the data
4. *Testing*
   The goodness of fit between the observed variance-covariance matrix, and the matrix implied by the model is assessed
5. *Modification*
   The model may then be altered in order to improve the goodness of fit

8.5.2 Analysis strategy

The initial stage in path analysis is model development (model specification). I will map out my hypothesised relationships between the wealth index and other SEP indicators, based on descriptive analyses, explicit assumptions, and theory. Path analysis will then be carried out using the software package Mplus Version 5.[262]

The association between the wealth index and each of its hypothesised socio-economic determinants will be assessed using a series of univariate path models; these will be referred to as 'unadjusted' models.

Adjusted analyses will then be conducted, such that a model will be run for each of the proposed determinants of the wealth index, simultaneously estimating the relationships between the wealth index, the determinant, and urban/peri-urban/rural area. I will use this to assess whether the relationships are still important once the effects of area of residence have been accounted for.

A full path model with the full set of wealth index determinants will then be run to estimate the fully adjusted relationships, direct and indirect effects. Models will initially be run using complete case analysis and ignoring the sampling design of the study. The final model will then be run using 'full information' estimation, i.e. incorporating all households with and without complete data, to explore whether missing data are introducing any bias. The final model will also be run adjusting for clustering and unequal probabilities of selection introduced by the sampling methods.

8.5.3 Variables

The determinants of the wealth index used in the models are: per capita consumption expenditure, education of the household head, area of residence, and community infrastructure.

Due to skewness and kurtosis of the continuous wealth index score, quintiles of the wealth index were used as an ordered categorical variable. Also due to skewness and kurtosis, the log of per capita consumption expenditure was used. Education of the household head was used as a three-category variable: no education or pre-school only, partial or completed primary school, and secondary or above. Education was used with fewer categories than in previous sections of this thesis in order to simplify modelling. Education was used as two dummy variables; none/pre-school only was selected as the reference category, and dummies were used for primary school (partial or completed) and secondary or above. Area of residence is the three category variable for urban, peri-urban or rural residence. Urban areas were selected as the reference category, and dummies were used for peri-urban and rural areas.

Community infrastructure is a measure of the services and facilities available in an area. The definition of a community in IHS2 is a census enumeration area (EA). These boundaries are administrative and may not represent boundaries of what might be recognised by residents as a 'community'. Although the literature makes a distinction between community and neighbourhood (an area defined by factors other than residents' perceptions) [315], the term community will be used for consistency with the terminology used in IHS2. Community infrastructure is measured at the EA level and uses both aggregates of household level data and indicators from the IHS2 community questionnaire. The available indicators were a mixture of binary and continuous variables. Continuous variables included both proportions (e.g. of households with electricity) generated from aggregates of household-level data, and distances (e.g. distance to the nearest primary school) from the community questionnaire. The reliability of the distance data could be questionable, since it is estimated by the community questionnaire respondents in kilometres or miles, which many people would not be able to accurately estimate. The distance variables were dichotomised to indicate whether or not the particular service/facility was available/present within the community (i.e. the service/facility was present in the community if the distance was recorded as zero in the community questionnaire, or the service/facility was *not* present in the community if distance was recorded as greater than zero). Whilst this may mean that some communities are coded as not having a facility/service, when in fact one is located in a close neighbouring community, this approach may remove some of the uncertainties about data quality. For most indicators, the majority of communities that do not have the facility/service within the community tend to be located a non-trivial distance (>5km) from the facility/service. In order to simplify generation of the infrastructure variable, I also dichotomised the proportion variables from household-level aggregates. The distributions of original continuous variables and the details of the dichotomisations are presented in **Appendix E.** All indicators used to construct the community infrastructure variable were therefore binary.

The infrastructure variable was generated in Stata using PCA with polychoric correlations. PCA with polychoric correlations was used in preference over including the ordinal variables in standard PCA, since it has been shown to produce the most accurate estimate of the proportion of variance in the indicators explained by the first principal component, and this will be important for assessing the quality of the infrastructure variable.[293] It was decided to generate the infrastructure score and use it as an observed variable in a path model, rather than use it as a latent variable in a full Structural Equation Model (SEM). This was primarily in order to simplify the model. A further advantage of this approach is that it facilitates the running of models on subsets of the population (e.g. urban, peri-urban or rural residents), whilst still using a measure of infrastructure generated on the full population. Path models using the score generated through PCA with polychoric corrections and a full SEM using infrastructure as a latent variable were found to be very similar (data not shown).

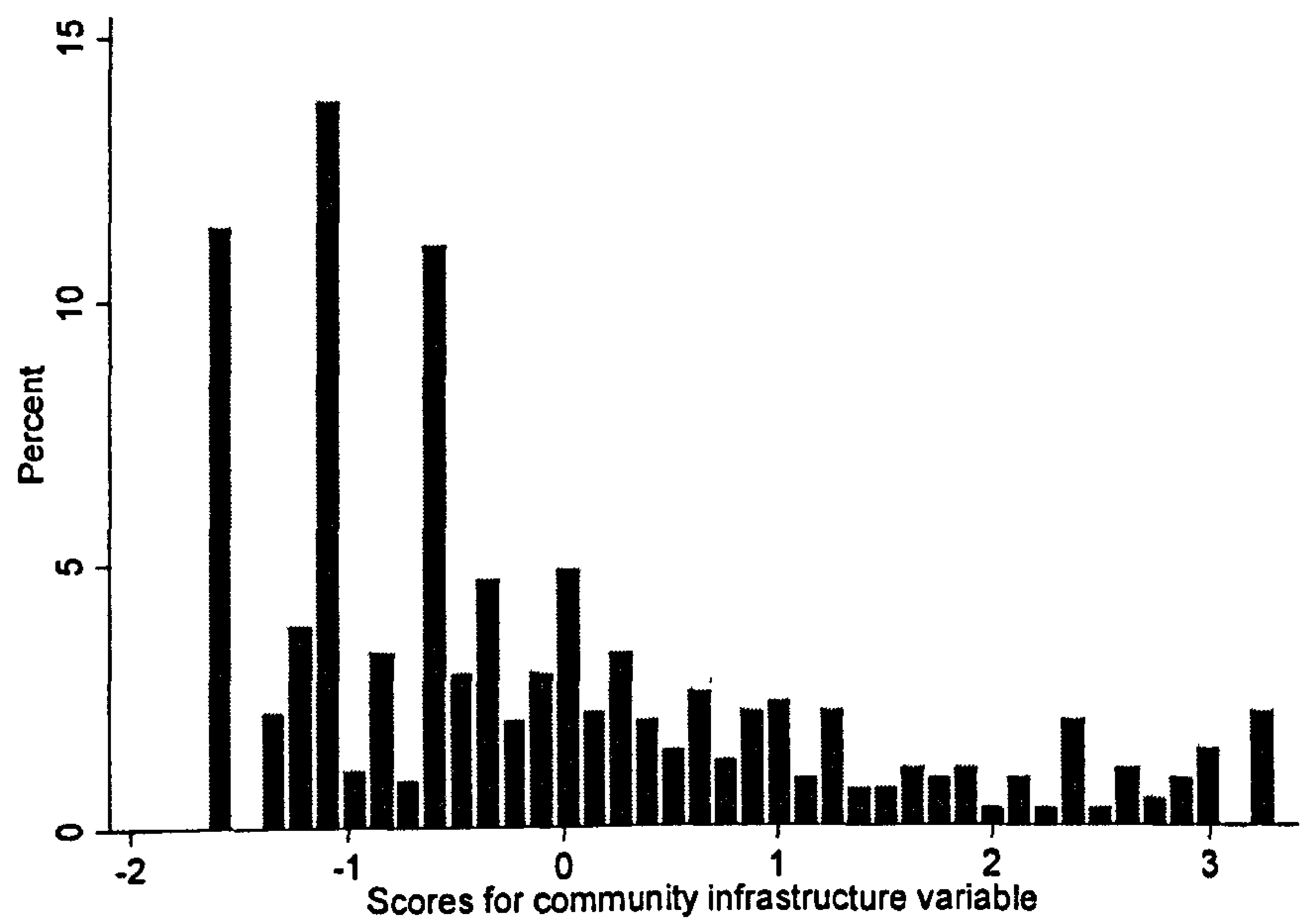
The variables used to generate the infrastructure score, their missing data levels, and the weights assigned to them through PCA with polychoric corrections are detailed in **Table 8.1**. For the composite score, there are 260 households (13 communities) with missing values (2.3%). Presence of a government primary school was initially considered as an indicator, but was found to have a low eigenvalue in the PCA; its exclusion increased both the cronbach alpha coefficient and the proportion of variance explained by the first principal component.

For the final set of indicators used, cronbach alpha coefficient is 0.75, and the first principal component from the PCA with polychoric corrections explains 52% of the total variance in the indicators, indicating that the indicators map well onto a single concept. All weights assigned by PCA are intuitive, with the absence of a service/facility being given a negative weight, and the presence of the service/facility having a positive weight. The strongest weights are assigned to whether any households in the community have an electricity supply. The infrastructure score shows some deviation from normality (**Figure 8.1**), with some clumping of scores at low values, but I did not consider this sufficiently problematic to justify using a categorised version of the score. Community infrastructure was used as a continuous variable at the individual level although scores for all households within a community are identical.

Table 8.1: Indicators of community infrastructure

Indicator	*Weight from PCA with polychoric corrections*	*Description*	*Percentage of households with the facility/service*	*Number (%)households with missing data*
Accessible				
- No	-0.414192	Whether vehicles can pass on the main road through the community all year	74.1	0
- Yes	0.141972			
Public transport				
- No	-0.222306	Whether public buses, minibuses, or matola regularly stop in the community		
- Yes	0.263618		44.6	20 (0.2%)
Daily market				
- No	-0.180824	Whether there is a daily market		
- Yes	0.398559		29.8	0
Piped water				
- No	-0.148336	Whether any households in the community have access to piped water		
- Yes	0.500091		20.9	0
Complete sanitation				
- No		Whether all households in the community have some toilet facility		
- Yes	-0.147459			
	0.317100		30.1	0
Tar/asphalt road				
- No	-0.132599	Whether there is a tar/asphalt road in the community		
- Yes	0.501060		18.8	120 (1.1%)
Secondary school				
- No	-0.130294	Whether there is a government secondary school in the community		
- Yes	0.448234		20.9	100 (0.9%)
Health clinic				
- No	-0.102306	Whether there is a government health clinic within the community		
- Yes	0.202950		32.0	20 (0.2%)
Electricity is available				
- No		Whether any households in the community have an electricity supply		
- Yes	-0.175736			
	0.527097		22.9	0

Figure 8.1: Distribution of the community infrastructure variable



8.5.4 Modelling

Due to the mixture of continuous and categorical variables in the model, models were run using weighted least squares mean and variance adjusted (WLSMV) estimation. This was initially chosen in preference over robust maximum likelihood (MLR) because it is less computationally intensive. Running the final model using MLR estimation produced results that were broadly similar to using WLSMV estimation, and did not alter the conclusions (data not shown).

Standardised parameters are reported to facilitate comparison between the strength of effects of different determinants of the wealth index.

As well as urban/peri-urban/rural area being a potential determinant of the wealth index, I hypothesised that the relative importance of other determinants could differ between these areas. For ease of interpretation, separate models were fitted for urban, peri-urban and rural areas rather than fitting interaction terms.

All regressions on quintiles of the wealth index have an ordered categorical dependent variable, and are run as ordinal probit models. For each ordered pair of wealth index categories, the model fits a probit regression. There are four probit regressions for the five categories; each regression has the same coefficient on each of the covariates. Negative regression coefficients can be interpreted as an increased probability of decreasing category of wealth index, and vice versa for positive coefficients. The probit model introduces a latent continuous variable underlying the quintiles of the wealth index; the standardised regression coefficients can be interpreted as the probability of a one standard deviation change in the underlying continuous wealth index variable attributable to a one standard deviation change in the covariate.

8.5.5 Goodness of fit tests

There are many goodness of fit indices that assess how well the observed covariance matrix fits with that estimated by the model. A set of several indices is generally used, since no single index has been shown to perform well in all situations.

The χ^2 statistic measures absolute goodness of fit, with a χ^2 statistic of zero indicating no difference between the sample covariance matrix and the covariance matrix implied by the model. The χ^2 statistic can be sensitive to minor model misspecifications with large sample sizes.[316] A non-significant χ^2 statistic indicates good fit. The comparative fit index (CFI) can be between zero and one, with one indicating perfect fit. The Tucker Lewis Index (TLI) also indicates better fit when its value is closer to one. The root mean squared error of approximation (RMSEA) is a measure of global fit; it estimates the discrepancy in fit per degrees freedom and is zero for perfect fit. Lower values of the weighted root mean square residual (WRMR) indicate better fit, although the authors of the Mplus package describe it as "not a well-studied fit statistics" that has not performed as well as expected.[317] Hu and Bentler[318] recommend the following criteria to judge a good fit, which I will use to assess the fit of models in this work:

Tucker Lewis Index (TLI)...	>0.95
Comparative fit index (CFI)...................................	>0.95
The root mean squared error of approximation (RMSEA)	<0.06
Weighted root mean square residual (WRMR)...........	<0.90

The pseudo R^2 will also be considered; with WLSVM estimation, Mplus uses the underlying continuous latent variable of the wealth index quintiles to estimate the R^2.

8.5.6 Model modification

The final step in path analysis is model modification, which involves a specification search to identify a model with better fit. Potential approaches include i) eliminating parameters that are not statistically significant, ii) including additional parameters, and iii) altering the proposed relationships between variables. In order to assess potential improvements to model fit, I will:

1. examine the statistical significance of parameters, and
2. examine the Modification Index and associated Expected Parameter Changes (EPC) provided by Mplus. The modification index is the expected value that the χ^2 statistic would decrease by if the suggested modification was made, such that large values indicate potentially useful changes. The EPC is the approximate value of the new parameter.

8.6 Results

8.6.1 Model specification

The wealth index is strongly associated with all of the proposed determinants, and the determinants are all strongly associated with each other (**Table 8.2**).

I hypothesise that the wealth index is a 'proximal' measure of SEP in comparison with the other SEP indicators being modelled (area of residence, consumption expenditure, education of the household head, and community infrastructure). The hypothesised relationships between the wealth index and its determinants are illustrated in **Figure 8.2**. Dependent variables are those with arrows going into them, and independent variables are those with arrows originating from them. Note that a variable can be both dependent and independent. Exogenous variables are those variables that are only independent variables, i.e. urban/peri-urban/rural and education of the household head in this model. Dotted lines demonstrate undirected pathways, i.e. correlations between error terms.

Table 8.2: Unadjusted associations between the wealth index and its determinants

Associations quantified using regressions with the top row of the table as the dependent variable. The three categories of education were treated as a linear variable. Quintiles of the wealth index were used in ordinal logistic regression.

	Wealth index	*Expenditure*	*Infrastructure*	*Education*	*Urban*
Wealth index	-				
Expenditure	β=3.9x10$^{-5‡}$	-			
Infrastructure	β=0.859‡	β=6682‡	-		
Education	β=0.969‡	β=8462‡	β=0.418‡	-	
Urban					-
Urban	1	1	1	1	
Peri-urban	-1.72	-15691	-0.663	-0.552	
Rural	-3.60 ‡	-25101 ‡	-2.25 ‡	-1.04 ‡	

‡ p<0.001

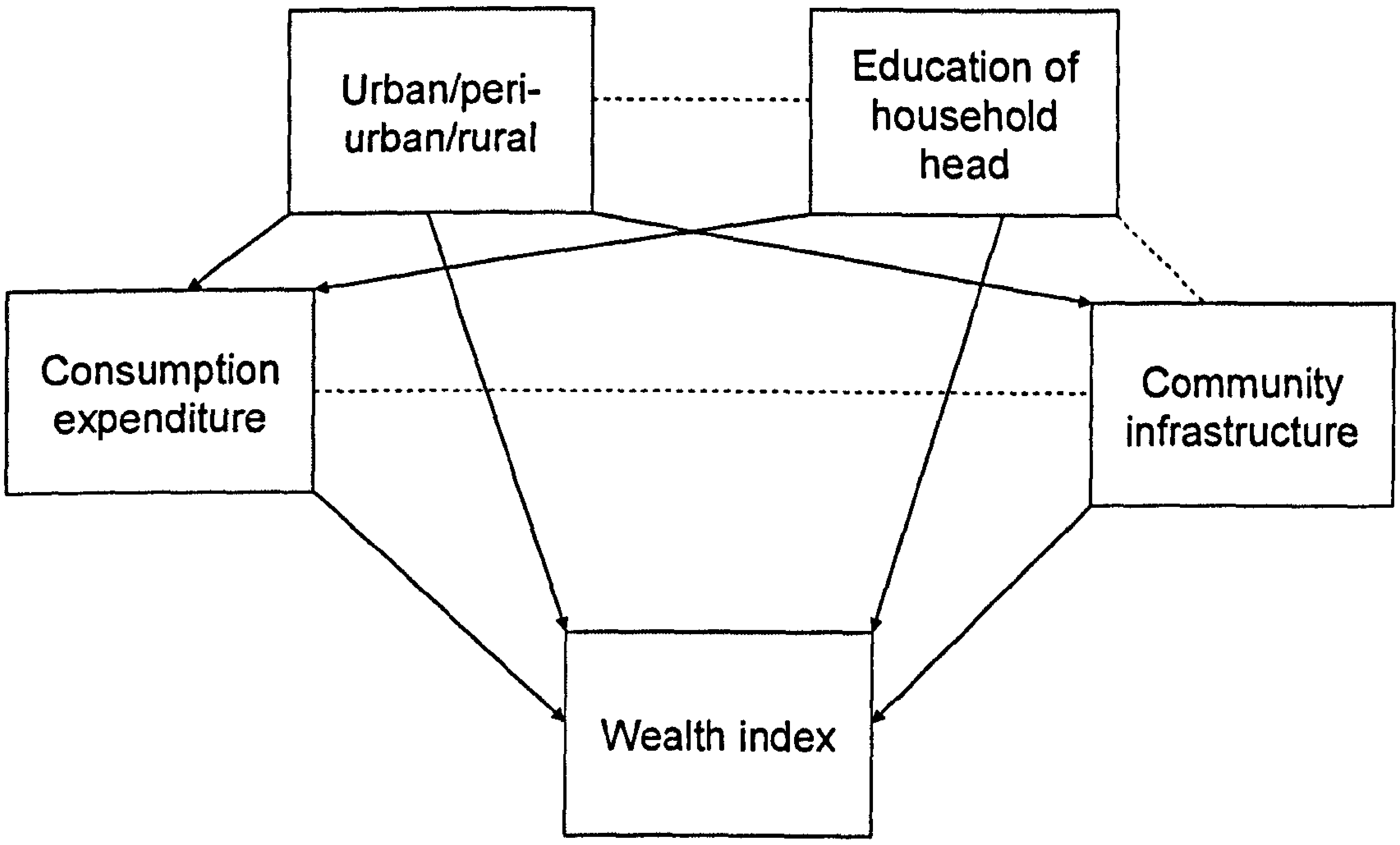
Education and consumption expenditure are hypothesised to affect ability to access consumer durables, housing, and services such as water, sanitation and electricity and therefore to affect wealth index score. They could also affect choices and preferences relating to consumer durable ownership. It is difficult to envisage a situation in which the wealth index score could precede any of these other indicators in causal terms. Similarly, urban/peri-urban/rural residence and community-infrastructure could affect the availability of, and preference for, items included in the wealth index, but it seems implausible that the relationship could go in the other direction. Urban/peri-urban/rural residence is also hypothesised to be a determinant of consumption expenditure.

The relationship between urban/peri-urban/rural residence and education of the household head is more complex, since education reflects a past experience whereas area of residence is current. Area of birth is likely to affect education, and both area of birth and education level are likely to impact on rural-urban migration patterns. This relationship is therefore entered into the path model as a correlation between error terms, shown by a dotted line in **Figure 8.2**.

Education is expected to affect consumption expenditure since it affects both purchasing power and consumption preferences and since education precedes expenditure temporally.

I am viewing urban/peri-urban/rural residence as a more distal indicator than community infrastructure, although this is questionable since it is arguably the level of infrastructure that defines an area as urban, peri-urban or rural. It is possible that community infrastructure has a bidirectional relationship with consumption expenditure. There may be a wider range of expenditure options and higher priced items in areas with higher community infrastructure, but it is also possible that households with higher consumption expenditure could locate themselves in areas with better infrastructure. Education of the household head represents a past experience, but community infrastructure is measured for current area of residence. Education therefore precedes community infrastructure temporally and certainly the two indicators are expected to be strongly associated, but I do not view education as a determinant of infrastructure. The relationship between education and community infrastructure is therefore represented in **Figure 8.2** as a dotted line, and is fitted in the path model as a correlation between error terms rather than as a regression.

Figure 8.2: Hypothesised determinants of the wealth index



8.6.2 Model Results

The unadjusted analysis demonstrates that all of the hypothesised determinants of the wealth index have a strong association with it. None of these relationships lose statistical significance after adjusting for urban, peri-urban or rural residence (**Table 8.3**).

In the full model, the standardised regression coefficients are all statistically significant apart from those for the two area dummies for peri-urban and rural areas (**Table 8.3**). To some extent, this goes against my original hypothesis that area of residence would be a strong determinant of the wealth index, although it is possible that all of the effect of area is mediated through community infrastructure, which remains highly statistically significant in the full model. The standardised regression coefficient for community infrastructure is smaller in magnitude than the coefficient for expenditures, which again goes against my initial hypothesis. It appears that household-level SEP indicators (education and expenditures) are stronger drivers of the wealth index than community-level indicators (area and community infrastructure), although community indicators are certainly important factors. When the indirect and direct effects of education and area are examined, the effect of rural residence on wealth index score is strong and highly statistically significant (**Table 8.4**). The effect of peri-urban areas is of lower magnitude, and is not statistically significant. It is possible that peri-urban areas do not differ from urban areas in their impact on the wealth index, or that the small sample size in peri-urban areas has lead to insufficient power to assess the difference. Education has both direct and indirect effects on wealth index score (**Table 8.4**).

For the full model of the determinants of the wealth index, the Chi squared statistic indicates poor model fit; this index is, however, subject to bias when used with large sample sizes. The CFI, TLI, RMSEA, and WRMR all indicate good fit and fulfil Hu and Bentler's criteria for good model fit (**Table 8.5**).[318]

Modification indices did not suggest any theoretically plausible amendments to the model specification.

The R^2 for quintiles of the wealth index was 0.405 for the full model (**Table 8.5**). This indicates that approximately 40% of variance in quintiles of the wealth index is being explained by the predictors included in the model.

Using full information estimation, where all cases are included in the analysis regardless of missing data, had minimal impact on the parameter values and no impact on interpretation of results (data not shown). Although the percentage of missingness is minimal (3%), the analysis using full information requires the unverifiable assumption of a missing at random mechanism, given the other variables in the model.

The correlations between all variables included in the full path model are shown in **Appendix F**.

Table 8.3: Results of path analysis models of determinants of the wealth index

A: Associations with the wealth index

Unadjusted†, area-adjusted‡, and full§ path analysis models (standardised ordinal probit regression coefficients); direct effects only are presented

Variable	Unadjusted analysis	Adjusted analysis			Full model
Log of per capita consumption expenditure	0.718***	0.536***			0.351***
Education of the household head					
- None/pre-school	-		-		-
- Primary only	0.304***		0.277***		0.268***
- Above primary	1.264***		0.912***		0.776***
Community infrastructure	0.506***			0.332***	0.283***
Area of residence					
- Urban	-	-	-	-	-
- Peri-urban	-0.971***	-0.879***	-0.581***	-0.836***	-0.235
- Rural	-1.996***	-1.795***	-1.578***	-1.351***	-0.736*

†unadjusted models are those exploring the relationship between quintiles of the wealth index and a single proposed determinant of the wealth index

§full model uses 'complex' type analysis, incorporating sampling weights and adjusting for clustering introduced by the sampling design (these are not included in the unadjusted and partially adjusted path models)

‡area-adjusted models are those exploring the relationship between quintiles of the wealth index, a single proposed determinant of the wealth index, and urban/peri-urban/rural area

***$p<0.001$
**$p<0.01$
*$p<0.1$

B: Other coefficients from the full path analysis model

Full path analysis model (standardised linear regression coefficients); direct effects

Independent Variable	Dependent Variable	
	Log of per capita consumption expenditure	Community infrastructure
Education of the household head		
- None/pre-school	-	
- Primary only	0.139***	
- Above primary	0.599***	
Area of residence		
- Urban	-	-
- Peri-urban	-0.119	-0.623
- Rural	-0.312*	-2.099**

***$p<0.001$
**$p<0.01$
*$p<0.1$

Table 8.4: Direct and indirect effects on the wealth index of education and area of residence in the full sample model

Variable	Direct	Indirect	Total
Full sample model (N=10,943)			
Education of the household head			
- *None/pre-school*	-	-	-
- *Primary only*	0.268***	0.049**	0.317***
- *Above primary*	0.776***	0.210***	0.986***
Area of residence			
- *Urban*	-	-	-
- *Peri-urban*	-0.235	-0.221	-0.456
- *Rural*	-0.736*	-0.704***	-1.440**

***p<0.001
**p<0.01
*p<0.1

Table 8.5: Goodness of fit indices for the full model of determinants of the wealth index

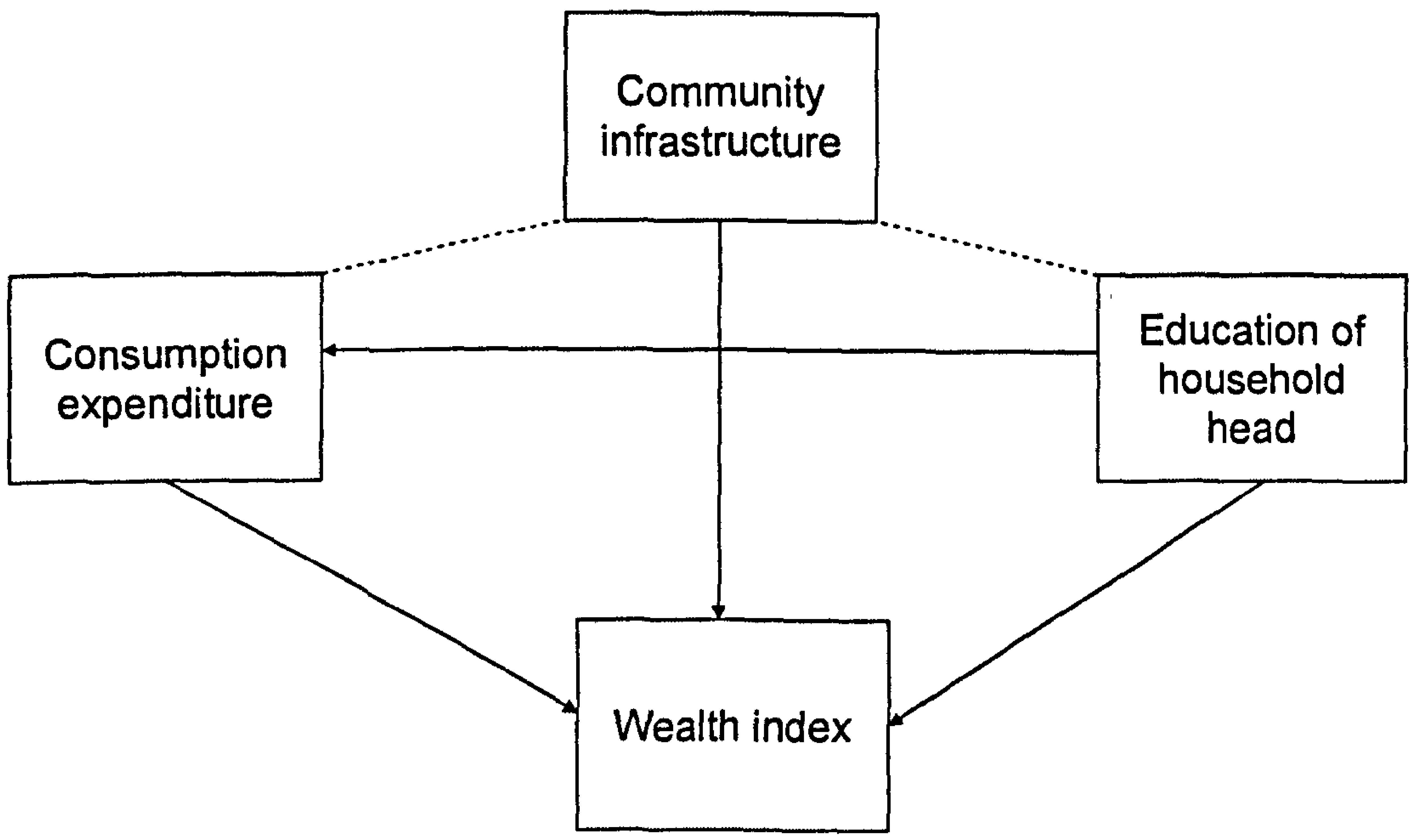
Index	Fit
Chi-squared statistic p value	<0.001
CFI	1.00
TLI	1.00
RMSEA	<0.001
WRMR	0.074
R^2 for quintiles of the wealth index (SE)	*0.405 (0.070)*

8.6.3 Area-specific models

Separate models for urban, peri-urban and rural areas were run, to investigate whether the importance of determinants of the wealth index differs between areas. The structure of the models is shown in **Figure 8.3.**

There is an indication that the determinants of the wealth index differ considerably between areas; although the strength of conclusions I can make about this difference is limited since I did not perform a formal statistical test of interaction, all parameter estimates are markedly different in the three areas, and all show clear trends when moving from rural to peri-urban to urban areas. Note that the model for urban households is run ignoring the sampling design, since the model incorporating clustering by strata and sampling weights could not be run; the Mplus output reported that standard errors could not be computed. Models for rural and peri-urban areas did not differ substantially when sampling was accounted for or ignored, so the bias in the standard errors introduced by not accounting for the sampling design in urban areas is thought to be minimal.

Figure 8.3: Area-specific model of determinants of the wealth index



Consistent with the results from previous chapters, the importance of consumption expenditure as a determinant of the wealth index is considerably higher in urban areas, intermediate in peri-urban areas, and lowest in rural areas (**Table 8.6**). Consumption expenditure is, however, an important and statistically significant determinant of the wealth index in all three areas.

Both the direct and indirect influences of education on the wealth index are also lowest in rural areas, intermediate in peri-urban areas, and highest in urban areas.

Contrary to my initial hypothesis, community infrastructure is also least strongly related with the wealth index in rural areas and most strongly associated in urban areas. The relative importance of community infrastructure compared with consumption expenditure is higher in urban areas compared with rural and peri-urban areas.

Although the chi-squared statistics are statistically significant in each area, indicating poor model fit, model fit is deemed acceptable by the CFI, TLI, RMSEA and WRMR in each area (**Table 8.7**).

The R^2 values indicate that the model explains just 11% of variance in the wealth index in rural areas, increasing to 52% in peri-urban areas and 71% in urban areas (**Table 8.7**). This indicates that there must be other determinants of the wealth index, particularly in rural areas. The R^2 would not, however, be expected to be very high given the many sources of variation in these data. In particular, the outcome of these analyses is quintiles of the wealth index score generated through PCA, which is likely to be subject to considerable measurement error. The comparison of the R^2 in each area, however, does demonstrate that the socioeconomic factors considered in these models are weaker predictors of the wealth index in rural areas compared with urban areas.

Table 8.6: Determinants of the wealth index; comparing i) full sample adjusted for area of residence and ii) area-specific models for urban, peri-urban and rural areas

Standardised ordinal probit regression coefficients

Variable	*Full population model N=10,943*		*Rural model N=8816*		*Peri-urban model N=697*		*Urban model N=1430*	
	Direct	**Indirect**	**Direct**	**Indirect**	**Direct**	**Indirect**	**Direct**	**Indirect**
Log of per capita consumption expenditure	0.351***		0.340***		0.619***		0.991***	
Education of the household head								
- *None/pre-school*	-	-	-	-	-	-	-	-
- *Primary only*	0.268***	0.049**	0.155*	0.037***	0.633*	0.154*	1.521***	0.254**
- *Above primary*	0.776***	0.210***	0.597***	0.146***	1.351***	0.428***	1.887***	0.854***
Community infrastructure	0.283***		0.202***		0.381***		0.703***	
Area of residence								
- *Urban*	-	-						
- *Peri-urban*	-0.235	-0.221						
- *Rural*	-0.736*	-0.704***						

*** = p<0.001
** = p<0.01
* = p<0.1

Table 8.7: Goodness of fit indices for path models of determinants of the wealth index in each area

Index	*Fit*			
	Full model	*Rural areas*	*Peri-urban areas*	*Urban areas*
Chi-squared statistic p value	<0.001	<0.001	<0.001	<0.001
CFI	1.00	1.00	1.00	1.00
TLI	1.00	1.00	1.00	1.00
RMSEA	<0.001	<0.001	<0.001	<0.001
WRMR	0.074	0.003	<0.001	<0.001
R^2 (SE)*	0.405 (0.070)	0.111 (0.010)	0.516 (0.071)	0.710 (0.034)

Missing data levels were low; complete data were available for 99% of households in urban areas, 94% of households in peri-urban areas, and 97% of households in rural areas. Using 'full information' analysis in Mplus yielded results very similar to the complete case analysis presented above (data not shown). As with the full sample model, the analysis using full information requires the unverifiable assumption of a missing at random mechanism.

No model modification indices above the minimum level determined by Mplus were suggested.

The correlations between all variables included in the full path model are shown in **Appendix F.**

8.6.4 Further potential determinants of the wealth index

Further potential determinants of the wealth index were also explored. Potential determinants considered include: i) occupation, ii) demographic factors such as household size and characteristics of the household head, iii) length of residence in current village, and iv) recent economic shocks.

Occupation

Models involving occupation were run, but the nominal nature of the occupation variable meant that estimation of the full model was particularly problematic. The software could not fit a model involving a nominal model that was both a dependent variable (depends on education and area), an independent variable (for expenditures and the wealth index) and correlated with another variable (community infrastructure). Simpler models involving restricted sets of the wealth index determinants indicated that occupation is also an important predictor of the wealth index, although the improvement to the R^2 for quintiles of the wealth index was minimal (data not shown).

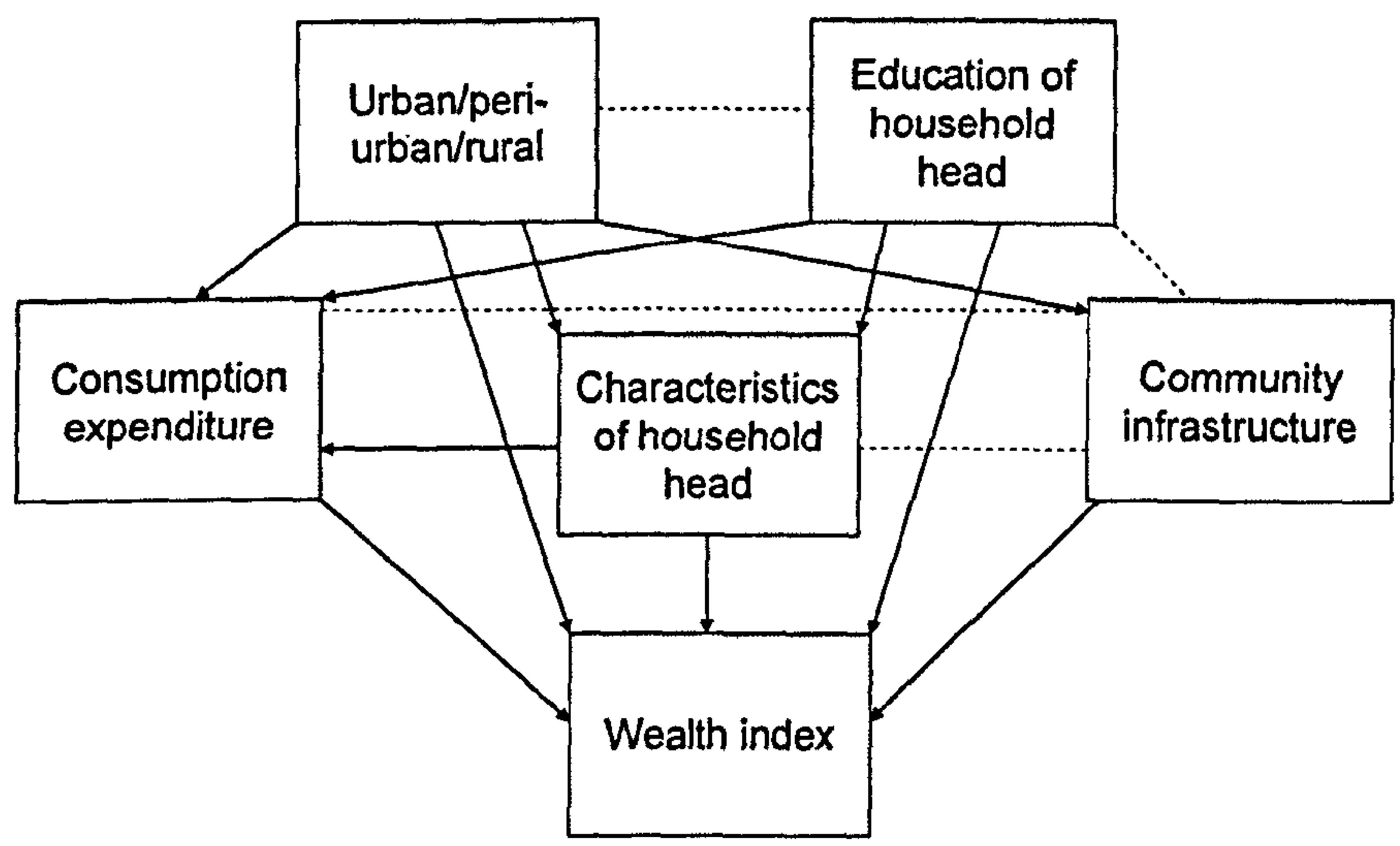
Household demographics

The full model and area-specific model of the core wealth index's determinants was re-run with the addition of sex and marital status of the household head **(Figure 8.4)**. Both of these factors were found to be independent predictors of the wealth index, but as with occupation there was minimal increase in the R^2 value for quintiles of the wealth index (data not shown).

Other factors

Chi squared tests for trend and ANOVAs demonstrated that there was no evidence of an association between quintiles of the wealth index and length of time the household head had been resident in the community, age of household head, household size, and whether the household had suffered various types of economic shock (data not shown). These factors were therefore not further explored as potential determinants of the wealth index.

Figure 8.4: Determinants of the wealth index, including characteristics of the household head



8.6.5 Excluding community-level indicators from the wealth index

The full model of the wealth index determinants (**Figure 8.2**) was run using the wealth index that excludes those indicators primarily determined at the community level (electricity, water source, and sanitation facilities; see **Section 6.5.4** for more details).

Surprisingly, the importance of community infrastructure is not markedly lower in the wealth index excluding community-level indicators compared with the wealth index including the full set of core assets (**Table 8.8**). Coefficients for expenditures, education, and area are slightly increased in the model of the wealth index excluding community-level factors.

The model has good fit, and the R^2 value for the wealth index excluding community level factors is slightly higher than for the wealth index including all core indicators (**Table 8.9**).

As with the model using the core wealth index, modification indices did not suggest any plausible model specification amendments.

Missing data levels are low (97% of households have complete information), and using full information analysis does not substantially alter results (data not shown).

Correlations between all variables in the model are shown in **Appendix F**.

Table 8.8: Determinants of the wealth index excluding community-level indicators

A: Standardised ordinal probit regression coefficients of associations with quintiles of the wealth index

Variable	*Wealth index N=10,943*		*Wealth index excluding community indicators N=10,971*	
	Direct	*Indirect*	*Direct*	*Indirect*
Log of per capita consumption expenditure	0.351***		0.401***	
Education of the household head				
- *None/pre-school*	-	-	-	-
- *Primary only*	0.268***	0.049**	0.395***	0.047*
- *Above primary*	0.776***	0.210***	0.849***	0.213***
Community infrastructure	0.283***		0.274***	
Area of residence				
- *Urban*	-	-	-	-
- *Peri-urban*	-0.235	-0.221	-0.339	-0.332
- *Rural*	-0.736*	-0.704***	-0.831	-0.808***

***p<0.001
**p<0.01
*p<0.1

B: Standardised linear regression coefficients of other associations in the model

Independent variable	*Dependent variable*			
	Wealth index N=10,943		*Wealth index excluding community indicators N=10,971*	
	Log of per capita consumption expenditure	Community infrastructure	Log of per capita consumption expenditure	Community infrastructure
Education of the household head				
- *None/pre-school*	-		-	
- *Primary only*	0.139***		0.118**	
- *Above primary*	0.599***		0.531***	
Area of residence				
- *Urban*	-	-	-	-
- *Peri-urban*	-0.119	-0.623	-0.212	-0.863
- *Rural*	-0.312*	-2.099**	-0.414**	-2.343**

***p<0.001
**p<0.01
*p<0.1

Table 8.9: Goodness of fit indices and R^2 for the wealth index for the model of determinants of the wealth index, comparing wealth indices using i) the full set of core assets and ii) excluding community-level indicators

Index	*Fit*	
	Wealth index models	*Wealth index with no public service indicators*
Chi-squared statistic p value	<0.001	<0.001
CFI	1.00	1.00
TLI	1.00	1.00
RMSEA	<0.001	<0.001
WRMR	0.074	0.029
R^2 (SE)*	0.405 (0.070)	0.431 (0.074)

8.7 Discussion

A household's position in the wealth index hierarchy is determined both by household- and community-level socio-economic factors. Although the direct effects of the area indicators themselves are not statistically significant, rural residence has a strongly significant indirect relationship with the wealth index through the other SEP indicators. Community infrastructure is an important determinant of the wealth index both overall, and in each area, but the standardised coefficients for the household level SEP indictors are of greater magnitude than the coefficient for community infrastructure. The correlations between indicators (**Appendix F**) show that community infrastructure is correlated with all of the other socio-economic factors in the model, but its strongest correlation is with the wealth index. Thus although household-level SEP indicators are also strong determinants of the wealth index, community infrastructure is also an important determinant, and its importance is greater for the wealth index than for other SEP indicators. As hypothesised, inequalities in the wealth index therefore represent a mixture of household- and community-level effects, complicating interpretation and policy implications of results.

The proportion of variance in the wealth index explained by the models is low; 40% in the full sample model. This implies that the wealth index must have other determinants in addition to those included in this model; although the expected values of R^2 would not necessarily be very high given that there are many sources of variation in the data, and since the outcome is an ordinal variable from a PCA score that is subject to considerable potential measurement error. Occupation and demographic factors were also shown to be statistically significant predictors of the wealth index, but did not increase the R^2 for the wealth index. Since the majority of the variance in wealth index scores is unexplained by the socio-economic factors in this model, the argument that the wealth index cannot really be seen as a readily-understood exposure in social epidemiology is reinforced.

The area specific models show that the relationship between the wealth index and each of its determinants is strongest in urban areas, intermediate in peri-urban areas, and lowest in rural areas. This corresponds with a higher R^2 in urban areas (0.71) compared with peri-urban (0.52) and rural (0.11) areas. This means that these analyses shed only very limited light on the socio-economic processes giving rise to wealth index scores in rural areas. In rural areas, wealth index score must be strongly determined by factors other than those included in these models. The nature of these factors remains unknown, and these results cast further doubt on the ability to interpret results and draw clear policy implications from research using the wealth index in rural areas.

Excluding community level indicators from the wealth index did not substantially reduce its association with community infrastructure. This demonstrates that all indicators included in the core wealth index are partially determined at the community-level, not just those related to publicly-provided services.

It is important to note that the models used in this analysis are probably not the only models that would fit the data; it is possible that alternative specifications with different relationships between the variables could have resulted in an equally good model fit. Caution is also necessary regarding the interpretation of 'direct' and 'indirect' effects; these relate only to the model under consideration. Direct effects are those not mediated by any other variables in the specified model; there may be other mediating factors not included in the model. They can only be assumed to be causal in the absence of unobserved confounding[319], and there is a possibility that indirect effects have been underestimated due to measurement error in mediators.[320]

8.8 Chapter Key Messages

1. The wealth index is determined by both household- and community-level socio-economic factors
2. Excluding community-level indicators from the wealth index does not reduce the importance of community infrastructure as a determinant
3. Very little is still known about the determinants of the wealth index in rural areas

8.9 Next steps

This chapter has demonstrated that there remains considerable uncertainty about the socio-economic processes leading to a wealth index hierarchy. The next step in this thesis is to explore potential alternatives to the wealth index that could be used in epidemiological studies in low- and middle-income countries, discussing the strengths and limitations of alternative indicators and whether they might be considered preferable to the wealth index.

Part V: What are the alternatives to the wealth index?

9. Alternatives to the wealth index

Part V of the thesis explores the potential alternatives to the wealth index. In this chapter, potential indicators are described and discussed. For those alternative SEP indicators that are available in the Malawi IHS2 dataset, their agreement with the wealth index and with consumption expenditure is quantified. Subsequently, the socio-economic processes contributing to some of these potential alternative SEP indicators are explored.

9.1 Chapter objective & hypotheses

The overall chapter objective is:

- To identify and explore potential alternatives to the wealth index

Specific objectives will be detailed in each section of the chapter.

My main hypotheses are:

1. Alternative measures of SEP will result in considerable differences in the predicated socio-economic hierarchy compared with the wealth index
2. Subjective measures of SEP will offer certain advantages over the wealth index; in particular they may be less influenced by community-level factors

9.2 Alternatives to the wealth index

In analyses of DHS and other existing datasets, choice of SEP indicator is restricted by data availability. For primary data collection, however, there are a wide range of options available for SEP measurement. Epidemiologists using the wealth index in low- and middle-income settings may perceive that there are few alternatives to the wealth index that are feasible within an epidemiological study, but I would argue that this is not the case. There is a vast literature on the measurement of SEP, and it is neither possible nor appropriate to fully review it here. Broadly speaking, indicators range from those measuring absolute poverty/deprivation to those measuring relative SEP within a population, from those focusing on monetary aspects of living standards to those taking a broader view of SEP, from those attempting to measure objective characteristics to those measuring subjective concepts. The choice of indicator should depend on the study setting and objectives, the reason for collecting SEP data and its proposed relationships to other variables of interest in the study. Feasibility issues and the available resources will also need to be considered.

The focus of this chapter will be on SEP indicators that are potentially useful and plausible for epidemiological studies in low- and middle-income settings. It will never be the case that a single SEP indicator is 'better' than all others, and many studies will require multiple indicators of SEP. In my view, however, some general desirable characteristics of SEP indicators for epidemiological research in low- and middle-income settings can be identified:

1. Epidemiological studies cannot generally afford to dedicate large amounts of time or money to SEP indicator data collection, since SEP is generally one element of a much larger data collection process
2. The indicator should be reliable and reproducible, suffering from minimal recall bias
3. Given that trust is important both to ensure high participation rates and to improve the accuracy of responses, SEP indicators should ideally not involve broaching sensitive topics or make respondents suspicious of the intentions of researchers
4. SEP indicators should capture locally-relevant aspects of social stratification, which may differ markedly across settings
5. The social stratification processes underlying the SEP indicator should be well-understood
6. Following on from point 5, the policy implications of the SEP indicator should be clear if the focus of the study is to quantify the inequalities or determinants of a health outcome, and clear hypotheses should be present for the causal pathways between the SEP indicator and the health outcome

The main appeal of the wealth index for primary data collection is the simplicity of data collection. The questions required for a wealth index are simple, easy to collect and do not consume a substantial amount of interview time. The perceived lack of recall bias compared with other SEP indicators may also be attractive, although this has been questioned by the work of Onwujekwe.[245] The questions are also probably less sensitive and potentially intrusive than those related to, for instance, income or expenditures. I demonstrated in **Chapter 8**, however, that there is a lack of understanding of the social stratification processes leading to a household's position in the wealth index hierarchy, that the relationship of the wealth index with other SEP indicators differs markedly between areas, and that the wealth index represents a mixing of household- and community-level effects. This lack of clarity in the concept of SEP being captured by the wealth index results in uncertain interpretation and policy implications of results demonstrated using the wealth index. There may be alternative SEP indicators with equally simple data collection that do not suffer from these problems associated with the wealth index. Given the generally low agreement between wealth indices and consumption expenditure, it may also be possible to identify improved proxies for consumption expenditure.

Morris *et al.* demonstrated that it is possible to generate a list of just ten expenditure items that, when summed, correlate highly with a full consumption expenditure measure (r=0.74).[32] This demonstrates that, where recent expenditure data are available, it is possible to create a proxy for consumption expenditure using a greatly reduced number of items. For those wishing to measure consumption expenditure but not having sufficient interview time and resources to dedicate to data collection, this is a good option providing the necessary data are available.

Other potential wealth index alternatives include participatory methods and subjective indicators. Participatory wealth ranking (PWR) is a technique widely used in development programs, but relatively little used in health research. Community members rank the wealth of households in their community, using a variety of methods such as focus group discussions and sorting techniques. PWR rankings were shown in a study in rural Bangladesh to be strongly associated with SEP indicators from survey data, with strong linear trends in income, asset ownership, consumption expenditure, value of housing material, and land ownership across wealth groups defined by PWR.[321] There is, however, evidence that PWR and a wealth index do not result in consistent household rankings.[322]

Subjective SEP appears to be a growing topic in the psychological literature, in both higher and lower income settings. It has been argued that subjective measures may 'more accurately capture subtle aspects of social status'; for example they may encapsulate the net effect of a variety of socio-economic factors which reinforce or counter-act each other.[323] In addition, they allow the research participants to direct the process of SEP quantification, rather than imposing pre-conceived notions and assumptions about the important socio-economic processes for a given population.

Subjective measures of SEP have been used in a variety of settings, and shown to be associated with a range of different health outcomes (reviewed in[324]). Several high-income setting studies have shown subjective SEP to be related to health independently of objective indicators.[325, 326] As with all SEP indicators, the pathways between SEP and health will depend on the health outcome, the setting, and other factors. Psychological pathways, however, may be of particular relevance for subjective SEP. Feelings of stress, anxiety, and inferiority associated with a perceived low position in the social hierarchy may adversely affect health, and equally positive feelings associated with a perceived higher SEP may have protective effects on health.[323] An important issue in the relationship between subjective SEP and self-rated health is that of 'negative affect'. Affect is a psychological term for an emotion, or subjectively experienced feeling. There is a school of thought that postulates that negative affect is a confounder of the relationship between subjective SEP and self-rated health, i.e. a third factor that leads to lower values of both. There is some evidence, however, that rather than acting as a confounder, negative affect mediates the relationship between subjective SEP and self-rated health, and therefore that adjustment for negative affect is inappropriate.[323, 325, 327] Subjective indicators require the assumption that there is inter-person comparability of question interpretation, i.e. a given question response means the same thing to all respondents in terms of SEP.

Various subjective SEP indicators are available. The MacArthur Network on Socioeconomic Status & Health[328] developed a measure of subjective SEP intended to capture the common effect of several socio-economic indicators. A pictorial ladder is presented to respondents, who are asked to place an "X" on the rung on which they feel they stand. One version of the ladder asks respondents to think specifically about several traditional SEP indicators – income, occupation, and education. Another asks them to place themselves according to where they sit in their community. This community ladder is designed to capture aspects of social standing not related to the traditional SEP indicators, such as religious and other community roles, and so on.

A similar concept to the MacArthur scale is where the ladder specifically refers to a ladder between poverty and richness, without mentioning income, education, occupation, or other traditional SEP measures. This is often referred to as an Economic Ladder Question (ELQ). Ravallion and Lokshin evaluate an Economic Ladder Question (ELQ) in which respondents are asked to "imagine a 9-step ladder where on the bottom, the first step, stand the poorest, and on the highest step, the ninth, stand the rich" and directed to say which step they stand on today.[329] The authors argue that this question, by using the words 'poor' and 'rich', focuses on economic welfare, but leaves it to the respondent to decide what it is that determines their economic welfare, rather than assuming that income, consumption expenditure, or something else is the important aspect of economic welfare. They discuss ways that the ELQ might differ from an objective measure of income, including: i) differences in the time period over which income is measured and the time period that informs subjective welfare rating, ii) differences in the impact of relative income on perception of affluence, and iii) "mood effects", i.e. transient and fixed idiosyncratic factors such as recent experiences, personality, and temperament.

Ravallion and Lokshin use data from the Russian Longitudinal Monitoring Survey (RLMS) from 1996 to explore the relationship of the ELQ with objective income measurement, and to explore the determinants of the ELQ. They categorise the income measure such that the groups have the same number of individuals in them as in the categories of the ELQ, and assess agreement between the measures. This demonstrates that agreement between the objective and subjective measures is weak, with considerable differential classification. A further exploration of the factors predictive of ELQ shows that health, education level, individual income (independently of household income), relative income, household size, proportion of adult men, age, marital status, uncertainty about finding a job, and ownership of certain consumer durables are all important determinants of the ELQ. Goldman *et al.* also explore the determinants of an ELQ, and show that in a sample of older Taiwanese people, income, education, schooling of children, occupation, car ownership, ethnicity, and number of sons are all important determinants of position on the ELQ.[330]

The determinants of the MacArthur scale/ELQ have also been explored in high-income settings, including in the Whitehall study where occupation, education, income, satisfaction with standard of living, and feelings of financial security have all been shown to be determinants of position on the ELQ.[331] Ostrove *et al.* showed that the relationships between an ELQ and objective SEP indicators different between racial groups in America.[326]

Other examples of subjective SEP indicators include measures of perceived consumption adequacy, and questions about whether income is sufficient to meet the household's needs.

For perceived consumption adequacy, respondents are asked to rate their household's consumption according to whether or not it is sufficient to meet the household's needs. Generally, several questions are asked relating to specific aspects of expenditure, such as food, clothing, housing, and healthcare. Two separate studies have shown that consumption expenditure is highly predictive of perceived consumption adequacy, and that poverty rates are similar using the objective and subjective consumption data.[275, 332] These studies also demonstrated that a wide range of other indicators tend to predict subjective consumption adequacy, including household size, educational levels of household members, employment of household members, health of household members, average community expenditure, and region.

Another possible subjective SEP measure is the Minimum Income Question (MIQ), which asks what is the minimum income needed to survive, and compares this with reported income. This method, however, suffers from the complications of income measurement in low- and middle-income countries. Other, broader measures might refer to concepts such as 'satisfaction with life', but it is arguably not appropriate to consider these as SEP indicators.

In addition to indicators of SEP itself, height of adults, anthropometry data of children, or health indicators such as child or maternal mortality rates are sometimes used as proxies for living standards, particularly at the country or area-level. Micklewright & Ismail suggested that child anthropometry data itself may be an appropriate tool for targeting of social policy.[333] They argue that anthropometry has fewer measurement problems than economic indicators, is more directly comparable across populations, and measures SEP at the individual rather than the household level. They advocate in particular the idea that average anthropometric scores for an area could be used as an indicator of area deprivation to guide the allocation of central funds for social policy.

In the Malawi IHS2, the potential alternatives to the wealth index are: education of the household head, an ELQ, a measure of consumption adequacy, and a measure of income sufficiency. Since food consumption forms the greatest share of overall consumption in this setting, the indicator of food consumption will be used alone in addition to the overall measure of consumption adequacy that includes food, housing, clothing, and healthcare consumption adequacy.

Occupation/employment data are also available within IHS2, but since these data do not follow an obvious hierarchical structure, they cannot be used in directly comparable ways. Furthermore, the occupational data within IHS2 have considerable limitations. Respondents are asked to describe (in free text) their main occupation over the past 12 months; this question resulted in a wide range of responses that are difficult to categorise meaningfully with a sensible number of groups. One issue with these data is that there is no obvious way to divide the 56% of household heads who are farmers. Data were also collected about participation in 'ganyu', casual labour. These data are also difficult to make sense of, since almost all individuals report partaking in some ganyu; even those whose main employment is for the government, a company, or a family business. The lack of useable employment/occupation data in IHS2 limits the scope of the objectives and conclusions within this thesis, since occupation is such a key aspect of SEP. Employment opportunities are affected by early life SEP, education, and area-level factors; work-life affects an individual's standing within their community, their income, and so on. Although measures of occupation are common in high-income country research, there has been relatively little methodological research on measures of occupation within low-income settings, aside from the lengthy processes of livelihoods evaluation used by some researchers.

9.3 *Agreement between socio-economic indicators*

This section explores the agreement between the wealth index and potential alternative SEP indicators that are available within the Malawi IHS2 dataset. I also explore the agreement between each of these potential alternative SEP indicators and consumption expenditure. This will facilitate estimation of the differences in the socio-economic hierarchy implied by each indicator, as well as provide guidance as to whether any of these indicators are a stronger proxy of consumption expenditure than the wealth index.

9.3.1 Objectives

1. Quantify the agreement between the wealth index and each of its alternatives
2. Quantify the agreement between per capita consumption expenditure and each of the potential alternatives to the wealth index

9.3.2 Methods

The core wealth index was used, as defined in **Section 4.3**. Per capita consumption expenditure was used, as defined in **Section 2.1.4.2**. The measurement of each of the alternative SEP indicators is described in **Section 7.4** (where their inclusion in the wealth index was explored), and their descriptive statistics are presented in **Appendix C (Table C.2)**. Subjective SEP measures were generated from interviewing the household head, but relate to the 'household's standard of living' and are thus assumed to be household-level measures.

For consumption adequacy, the indicators of food, housing, clothing and healthcare adequacy described in **Section 7.4** are combined to form a single index. This was done using PCA with polychoric correlations. The first principal component explained 64.5% of the variance in the indicators, and all weights were intuitive (i.e. 'less than adequate' received a negative weight, 'just adequate' received a positive weight, and 'more than adequate' received a higher positive weight) and roughly similar between the four indicators (**Table 9.1**). Since the score had considerable deviation from normality, it was used as quintiles.

Table 9.1: Weights assigned to consumption adequacy indicators

Aspect of consumption	*Adequacy for household's needs*	*Weight*
Food	*Less than adequate*	-0.360641
	Just adequate	0.346495
	More than adequate	0.958242
Housing	*Less than adequate*	-0.384830
	Just adequate	0.324183
	More than adequate	0.987109
Clothing	*Less than adequate*	-0.264346
	Just adequate	0.585220
	More than adequate	1.302772
Healthcare	*Less than adequate*	-0.298805
	Just adequate	0.378305
	More than adequate	1.001290

When assessing agreement between consumption adequacy and either the wealth index or consumption expenditure, quintiles of each measure were used. Since education, food consumption adequacy, the economic ladder question (ELQ), and income sufficiency all have different numbers and/or sizes of groups, it was not possible to measure agreement using quintiles of the wealth index or consumption expenditure. In each case, new categorised versions of the wealth index and consumption expenditure variables were created, such that group sizes were the same as the alternative SEP indicator, e.g. 44% of households placed themselves on the bottom step of the ELQ so new variables were created that had the lowest 44% of wealth index/consumption expenditure scores in the bottom group. Agreement between each SEP indicator and i) the wealth index and ii) per capita consumption expenditure was then assessed by agreement of classification into groups, and kappa statistics.

9.3.3 Results

All of the alternative SEP indicators would result in very different conclusions about the socio-economic hierarchy in this sample compared with the wealth index (**Table 9.2**). The percentage of households in the same group as the wealth index is highest for adequacy of food consumption, and lowest for overall consumption adequacy.

The percentage of households in the same group as consumption expenditure is low, or at best moderate, for all SEP indicators (**Table 9.3**). The only SEP indicator with lower agreement with consumption expenditure than the wealth index is consumption adequacy. Food consumption adequacy and the ELQ have the highest agreement with consumption adequacy, but in these cases still only approximately half of households are in the same group by the two indicators.

Table 9.2: Agreement of each SEP indicator with the wealth index

	Percentage of households with each level of agreement with the wealth index					
	Same group	*Moves 1 group*	*Moves 2 groups*	*Moves 3 groups*	*Moves 4 groups*	*Kappa (SE)*
Education of household head (N=11,203)	40.3	42.6	14.1	3.1	0.01	*0.15 (0.006)*
Perceived adequacy of food consumption (N=11,237)	49.6	44.4	5.9	N/A	N/A	*0.079 (0.008)*
Consumption adequacy (N=11,230)	24.2	33.6	22.8	14.1	5.2	*0.062 (0.005)*
Economic Ladder Question (N=11,226)	46.4	45.6	7.4	0.66	N/A	*0.15 (0.007)*
Income sufficiency (N=11,234)	34.6	40.2	16.5	8.1	0.72	*0.083 (0.005)*

Table 9.3: Agreement of each SEP indicator with consumption expenditure

	Percentage of households with each level of agreement with consumption expenditure					
	Same group	*Moves 1 group*	*Moves 2 groups*	*Moves 3 groups*	*Moves 4 groups*	*Kappa (SE)*
Wealth index (N=11,243)	28.9	33.5	20.4	13.6	3.6	0.11 (0.005)
Education of household head (N=11,240)	37.3	41.1	17.1	4.4	0.05	*0.11 (0.006)*
Perceived adequacy of food consumption (N=11,274)	53.1	42.0	4.9	N/A	N/A	*0.14 (0.008)*
Consumption adequacy (N=11,267)	25.7	34.3	22.7	11.7	5.6	*0.071 (0.005)*
Economic Ladder Question (N=11,263)	45.2	44.9	8.9	1.0	N/A	*0.13 (0.007)*
Income sufficiency (N=11,271)	34.2	39.9	16.4	8.6	0.97	*0.079 (0.005)*

9.3.4 Discussion

Each of the alternative SEP indicators leads to different conclusions about the relative positions of households within the socio-economic hierarchy. None of the SEP indicators explored here have strong agreement with consumption expenditure, although food consumption adequacy and the economic ladder question have stronger agreement than the wealth index. It is equally valid to say, however, that none of these indicators is a *worse* proxy for consumption expenditure than the wealth index. The lack of strong agreement between the subjective indicators and consumption expenditure is unsurprising, since it is known that many factors play a role in an individual's subjective ranking of their economic position.[326, 329-331]

Since there remain questions about the determinants of the wealth index, particularly in rural areas, and concerns about its appropriateness in rural areas, it could be argued that using one of the subjective SEP indicators instead of the wealth index is justifiable or even preferable. Education is generally considered a separate exposure to economic position, so would usually be used as a separate indicator in addition to an economic measure.

In this population, consumption expenditure has far stronger agreement with perceived food consumption adequacy than with the combined measure of perceived adequacy of food, housing, clothing, and healthcare. Since food makes up the highest proportion of consumption expenditure, this is perhaps unsurprising. It is also possible that non-economic factors more strongly affect the perceived adequacy of housing, clothing, and healthcare than the perceived adequacy of food. The perceived adequacy of housing and clothing may be strongly affected by relative comparisons with those within the individual's community. The perceived adequacy of healthcare is perhaps likely to be affected by the health status and age of the individual and other household members. For these reasons, I would advocate, at least in similar settings, the use of a food consumption adequacy indicator in isolation rather than in combination with other consumption adequacy indicators.

9.4 Modelling the determinants of alternative SEP indicators

9.4.1 Background

The wealth index was shown to be strongly determined by community infrastructure, as well as by household-level SEP (**Section 8.6**). Furthermore, I demonstrated that the proportion of variance in wealth index scores explained by socio-economic factors was low, particularly in rural areas. This questions the appropriateness of viewing the wealth index as a clearly-defined exposure, particularly in rural areas, and means that any implications that can be drawn involve an uncertain mixture of both household- and community-level considerations. Although some studies have explored the determinants of the ELQ[326, 329-331, 334] and consumption adequacy[275, 332], and there is an extensive psychological literature on the determinants of subjective well-being, it is not known how the determinants of these subjective indicators differ from those of the wealth index. Furthermore, although region and average community expenditure have been shown to affect both the ELQ and consumption adequacy, the importance of an aggregate measure of community infrastructure for these subjective indicators has, to my knowledge, not been investigated.

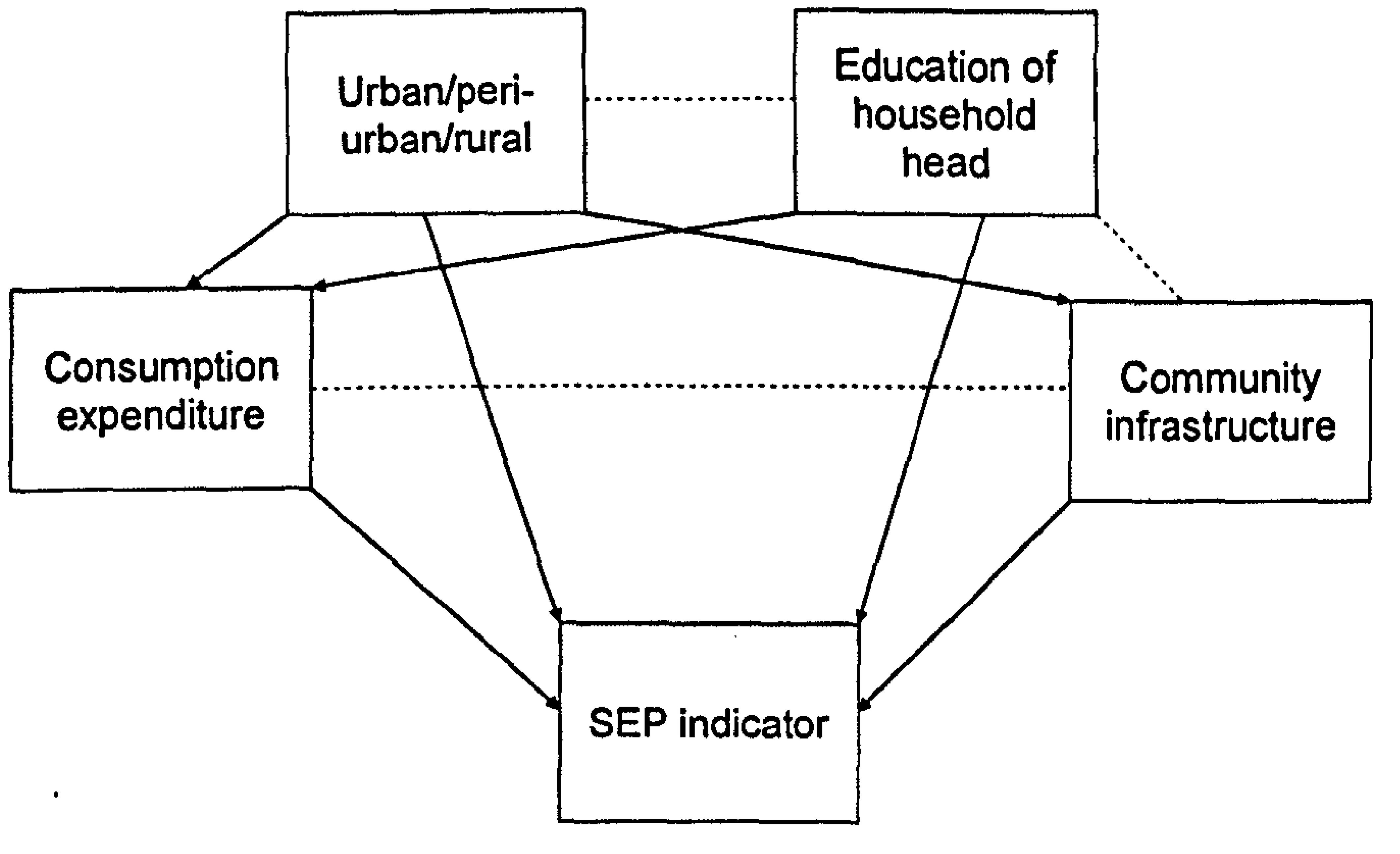
9.4.2 Objectives

1. Compare the determinants of the wealth index with those of subjective SEP indicators
2. Evaluate the importance of community infrastructure as a determinant of subjective SEP indicators

9.4.3 Methods

The path analysis model run to explore the determinants of the wealth index (**Section 8.5**) was re-run for each of: i) food consumption adequacy, ii) consumption adequacy, iii) economic ladder question, and iv) income sufficiency. Food consumption adequacy, the ELQ, and income sufficiency were used as defined in **Section 7.4.** Quintiles of consumption adequacy were used as defined in **Section 9.3.2.** All path analysis settings were as in **Section 8.5.** All SEP indicators were specified as categorical variables, all other variables were used as in **Section 8.5.** The models run are depicted in **Figure 9.1.** For comparative purposes, the results for the wealth index that were presented in **Chapter 8** are also given. As in **Chapter 8,** standardised regression coefficients from ordinal probit regressions are presented, which can be interpreted as the change in standard deviations of the underlying latent continuous wealth index score that would be expected from a one standard deviation change in the exposure variable. Goodness of fit will be judged using the same tests detailed in **Section 8.5.5.**

Figure 9.1: Determinants of subjective SEP indicators



9.4.4 Results

The most striking difference between the model of the wealth index and the models of the subjective measures of SEP is that the importance of community infrastructure is dramatically higher for the wealth index (**Table 9.7**). Of the four subjective SEP indicators, community infrastructure is only a statistically significant determinant of consumption adequacy, and in this case the coefficient is less than half that for the wealth index and the statistical significance is lower than for the wealth index.

The coefficient for log per capita consumption expenditure is broadly similar for the wealth index and all of the subjective SEP indicators. Differences are consistent with the patterns of agreement shown in **Section 9.3**.

Education appears to be a stronger determinant of the wealth index and the ELQ than the other subjective SEP indicators.

The indirect effect of rural area is strong and highly statistically significant for the wealth index; this is not the case for any of the subjective SEP indicators. Interestingly, the direct effects of peri-urban and rural areas are positive (compared with urban areas) for food consumption adequacy and consumption adequacy, although they are not statistically significant.

The models for all subjective SEP indicators have acceptable fit as judged by the CFI, TLI, RMSEA and WRMR (**Table 9.8**). Although the CFI and TLI values indicate perfect fit, this should not be over-interpreted. Each goodness of fit index should be interpreted cautiously, with reference to the other, in this case less optimistic, indices.

The proportion of variance explained by the variables in this model is low for each of the subjective indicators, and in all cases is considerably lower than for the wealth index (**Table 9.8**). Any conclusions that can be reached through this comparison, however, are limited since the sources of measurement error and extent of variation is likely to differ considerably between the subjective SEP indicators and the wealth index generated through PCA. The R^2 is highest for the ELQ, but this is still less than half the value of the R^2 for the wealth index. In order to investigate whether the difference in R^2 values between the wealth index and the other SEP indicators was primarily due to the stronger influence of community infrastructure on the wealth index, the determinants models for each SEP indicator were re-run excluding community infrastructure. Whilst the R^2 for the wealth index decreased by over 25%, the decrease for all other SEP indicators was less than 10% (**Table 9.8**). This resulted in a narrowing of the difference in R^2 values between the wealth index and the other SEP indicators, but a considerable difference remained. The subjective SEP indicators are, therefore, less strongly influenced by both the household- and community-level factors explored here compared with the wealth index.

Complete data are available for over 95% of households for all models, and using full information analysis did not result in substantial differences from the complete-case analysis presented here (data not shown). The full information analysis, however, relies on the unverifiable assumption that the data are missing at random given the variables in the model.

As with the wealth index, modification indices did not suggest any plausible model specification amendments.

Correlations between all of the variables in the models are presented in **Appendix G**.

Table 9.7: Modelling the determinants of the wealth index and determinants of alternatives to the wealth index

Standardised ordinal probit regression coefficients

Variable	Wealth index N=10,943		Food consumption adequacy N=10,976		Consumption adequacy N=10,970		Economic ladder question N=10,965		Income sufficiency N=10,973	
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Log of per capita consumption expenditure	0.351***		0.438***		0.364***		0.455***		0.356***	
Education of the household head										
- None/pre-school	-	-	-	-	-	-	-	-	-	-
- Primary only	0.268***	0.049**	0.176**	0.049***	0.136*	0.048***	0.318***	0.059***	0.113	0.047**
- Above primary	0.776***	0.210***	0.441***	0.221***	0.437***	0.214***	0.840***	0.265***	0.380***	0.208***
Community infrastructure	0.283***		0.060		0.095**		0.063*		0.037	
Area of residence										
- Urban	-	-	-	-	-	-	-	-	-	-
- Peri-urban	-0.235	-0.221	0.281	-0.165	0.262	-0.085	0.025	-0.024	-0.227	-0.052
- Rural	-0.736*	-0.704***	0.390	-0.205*	0.229	-0.293*	-0.016	-0.240*	-0.259	-0.185*

*** = p<0.001
** = p<0.01
* = p<0.1

Table 9.8: Goodness of fit for the models of determinants of the wealth index and alternatives to the wealth index

Index	Fit				
	Wealth index model	**Food consumption adequacy model**	**Consumption adequacy model**	**Economic Ladder Question model**	**Income sufficiency model**
Chi-squared statistic p value	<0.001	<0.001	<0.001	<0.001	<0.001
CFI	1.00	1.00	1.00	1.00	1.00
TLI	1.00	1.00	1.00	1.00	1.00
RMSEA	<0.001	<0.001	<0.001	<0.001	<0.001
WRMR	0.074	0.031	0.082	0.106	0.061
R^2 for SEP indicator (SE)	0.405 (0.070)	0.101 (0.017)	0.105 (0.019)	0.197 (0.024)	0.112 (0.029)
R^2 for SEP indicator when community infrastructure was excluded from the model (SE)	0.295 (0.054)	0.094 (0.014)	0.094 (0.016)	0.196 (0.027)	0.105 (0.025)

9.4.5 Discussion

Modelling the determinants of the subjective SEP indicators showed that community infrastructure is far less important for these indicators than for the wealth index. The importance of consumption expenditure is broadly similar for the wealth index and the subjective SEP indicators.

The proportion of variance in the subjective SEP indicators that was explained by the models was considerably lower than for the wealth index, indicating that the importance of the SEP indicators included in these models is perhaps lower for these subjective measures of SEP than for the wealth index. The differences in observed R^2 values could, however, be at least partially explained by the differences in measurement error and extent of variation between the wealth index and subjective SEP measures. These R^2 values are comparable to those reported for measures of consumption adequacy by Lokshin *et al.* and Pradhan & Ravallion, even though these studies included a considerably wider range of potential determinants in the models.[275, 332]

Subjective measures of SEP do not have the issue of mixing household- and community-level influences, but they also appear to have a complex web of determinants and are only relatively weakly influenced by the key socio-economic indicators education and consumption expenditure. Ravallion and Lokshin argue that subjective SEP is influenced by the respondent's frame of reference; e.g. a rural resident who has never left her village may rate her SEP as higher than an urban respondent partially because she has never witnessed the greater wealth of rich urban residents. The rural resident's frame of reference is smaller than, or at least different to the urban resident's.[335] This is an example of 'differential item functioning', a concept familiar in the educational testing literature whereby subsets of the sample respond differently to a given question; Ravallion described this as resulting in "a systematic difference in the scale used to assess SEP".[335] There is a body of psychology literature that explores the determinants of subjective well-being; this literature is generally not specifically focused on subjective SEP, it often concentrates on more general well-being such as life satisfaction, but the findings are certainly relevant to the interpretation of subjective SEP measures and could help the interpretation of inequalities demonstrated using these measures. However, effective policy development would require a clear understanding of the factors that affect people's rankings of their SEP in a given setting.

As discussed in **Section 8.7**, the models presented here may not be the only models that would fit the data, and caution is required in the interpretation of direct and indirect effects.

9.5 Chapter conclusions

Given the uncertainty about the socio-economic processes being captured by the wealth index, and the mixing of household- and community-level effects, epidemiologists may wish to seek alternatives to the wealth index. This chapter has identified and discussed some of the potential alternatives. For those indicators for which data are available in the IHS2 dataset, I have evaluated their agreement with the wealth index and with consumption expenditure, and explored their socio-economic determinants. In addition to selecting an alternative to the wealth index, an understanding of the strengths and limitations of different indicators may assist in the selection of an appropriate and complementary set of indicators to be used in a particular study.

I will now attempt to compare the strengths and weaknesses of the wealth index, potential alternatives, and the two main traditional SEP indicators used in low- and middle-income countries – consumption expenditure and education. I will discuss how well each of them meets the desirable characteristics of SEP indicators for epidemiological studies in low- and middle-income settings outlined in **Section 9.2**. After discussing each of the indicators, I present a tabulated summary of the pros and cons of each SEP measure, attempting to rate how well it meets each criterion as good, fair, poor, or unknown **(Table 9.9)**. This summary is intended primarily as a mind-map for drawing together and comparing the general strengths and weaknesses of the SEP indicators. The ratings are based both on the available evidence and, where evidence is limited or lacking, on my own judgement. They are therefore to some degree subjective and debateable, and furthermore are likely to differ between settings and studies. For instance, some purposes may require an absolute poverty line whereas for others a measure of relative position within a social hierarchy will suffice, or the data collection requirements or study setting may facilitate or preclude certain types of indicator. Income, whilst being a much-used indicator in higher-income settings, is not often used in low- and middle-income settings apart from in Latin America. This is largely because of concerns about its reliability and instability. Income data were not available in the Malawi IHS2 dataset and so could not be included in the analyses in this chapter. Income is therefore not considered further in this section. Occupation is also not further considered, since it is not a hierarchical measure of SEP and therefore cannot easily be used in the same way or compared with the wealth index.

The wealth index

Data collection for a wealth index is quick, cheap, and easily incorporated into a larger household questionnaire. Whilst its perceived reliability is high, the only published study demonstrated only moderate inter- and intra-observer reliability.[245] The questions necessary for a wealth index are not likely to cause offence or concern to the majority of participants, although the purpose of asking such questions could potentially be unclear and create suspicion; there is no published evidence on the acceptability of such questions. The issue of local relevance is pertinent to the wealth index; when the 'standard' set of indicators used by the DHS are used to construct a wealth index, the significance of these items to the local population is generally unclear and certainly varies considerably across locations. As was discussed in **Chapter 8**, the socio-economic processes underlying the wealth index hierarchy in the Malawi IHS2 data remain uncertain, particularly in rural areas. This uncertainty, coupled with the mixing of household- and community-level effects results in a lack of clarity surrounding proposed causal relationships to health and therefore policy implications.

Consumption expenditure

The interview time required to collect consumption expenditure data precludes its use for most epidemiological studies, with a consumption expenditure module typically taking approximately an hour to complete. The problems with reliability of consumption data are well known. Some examples include that longer recall papers have been shown to result in lower reported consumption[256] and that a longer list of expenditure items has been shown to result in a higher reported consumption total[257]. Although bias in all expenditure items is inevitable to some extent, those expenditures which are rarer or 'lumpier' such as healthcare, and those requiring multiple assumptions and imputations, such as rental value of housing, are likely to suffer from a greater degree of measurement error than, for example, food expenditures. This has lead to discussion of whether a restricted measure of consumption using only the more reliable aspects is preferable to a more comprehensive measure.[31, 336] A proposed advantage of consumption expenditure over income is that the questions are less sensitive and liable to adversely affect researcher-participant relationships[57], but there is little literature on participants' views of being asked consumption expenditure questions. The items included in an expenditure aggregate are generally tailored to the setting, and price indices are used to adjust measures for regional and temporal differences, ensuring that the aggregate measure is appropriate for all areas in a survey. Consumption expenditure measurement is grounded in economic theory; the concepts it is aiming to capture and how these may relate to health are well-understood.

Education

Data collection for education is simple and fast; it requires only one or two questions on a questionnaire. Response rates for education questions tend to be higher than for other SEP measures, and reliability is believed to be high.[19, 25] Measures of education, however, generally make little attempt to capture the quality of the education received.[25] The importance and role of education will differ between times and places. For instance as education becomes more widely available, the economic gains from a certain standard of education may decrease. This means that cohort effects should always be considered when using education as a measure of SEP. The local situation should also be considered when deciding which way of quantifying education is most appropriate – years of study completed, qualifications gained, or highest grade completed. The social stratification processes underlying education are clear, its relationship with health is well analysed[26, 316], and there are clear policy implications from inequalities demonstrated using education.

Subjective SEP measures

Four subjective measures of SEP were used in analyses of the Malawi IHS2 data: consumption adequacy, food consumption adequacy, perceived income sufficiency, and the economic ladder question. Each of these is very simple to measure, requiring a single question in a questionnaire. There is, however, considerable potential for participants to find the questions confusing or difficult to answer, although there is little discussion of this in the literature. A study in The USA that recorded subjective SEP on participants on two separate occasions with a six-month interval obtained a Spearman's rank-order correlation coefficient of 0.62 between the two measurements, demonstrating reasonable test-retest reliability.[323] By definition, subjective SEP measures are capturing a locally-relevant concept of social stratification, since participants themselves determine how and why they place themselves within the social hierarchy. The phrasing of the question, however, should be tailored to the local population to ensure that it is likely to be understood and get a high response rate. The evidence surrounding the determinants of subjective SEP was reviewed in **Section 9.2** and will not be repeated here; the number of studies is limited but considerably greater than for the wealth index, and importantly exploring the determinants of subjective SEP within a given study setting would be possible. A further advantage that subjective SEP measures have over the wealth index is that these indicators are not mixing household- and community-level effects in the same way that a wealth index does.

Participatory wealth ranking

Although no data on PWR were used in analyses in this thesis, it still represents a potential alternative to the wealth index if the study conditions are amenable. PWR represents a useful tool in certain settings and studies, but involves intensive data collection and is only feasible in relatively small geographical areas. Data collection for one study involving 500 households was completed over a two-day period, using only one fieldworker.[229] Whilst this is fairly rapid, this is a considerable amount of resources to dedicate to one measure, and whether or not it is justifiable will depend, amongst other factors, on the aims of the study. The same study in South Africa demonstrated extremely high agreement between three different processes of ranking households, indicating that PWR has high reliability.[229] The acceptability of the process of PWR has received little attention in the literature, although it is possible that the activities involved could be uncomfortable for some participants. PWR is certainly capable of capturing locally-relevant concepts of social stratification, since community members themselves generate the rankings and provide the information about why households were ranked in a particular way. This feature of the process also enables insight into the socio-economic processes being captured by the final measure.

Reduced consumption expenditure list

Morris' method of using a restricted set of consumption expenditure items can be a useful tool for those wishing to measure economic position without the data collection requirements of a full consumption expenditure measure. This approach, however, necessitates existing full and recent expenditure data from the setting of interest. If this is available, a reduced consumption expenditure list would seem to be the most appropriate indicator for those wishing to have a proxy for consumption expenditure. The methods of Morris *et al.* have not been replicated in published literature using other datasets, so the evidence about the reliability of this method is limited. Additionally, there will be recall bias associated with each of the items on the reduced list. Taken as a proxy for full consumption expenditure, issues of local relevance, understanding of social stratification processes, pathways to health, and policy implications should be similar to those for the full measure.

Conclusions

Contrary to perceptions, a range of potential alternatives to the wealth index exist that are feasible within epidemiological studies. All SEP indicators have advantages and disadvantages; no single indicator that can act as a panacea, and the properties of each indicator should be considered when selecting an appropriate and complementary set of SEP measures for a given study. There are, however, indicators that are feasible within epidemiological studies but that do not suffer from the same problems as the wealth index – for example subjective SEP indicators do not appear from my analyses to suffer from the same mixing of household- and community-level effects, there are considerably more studies exploring their determinants, their determinants would be simpler to explore in a given population, and they capture locally-relevant concepts of social stratification. Furthermore, I have shown that the ELQ has stronger agreement with consumption expenditure than the wealth index, indicating that this may be a good option when an economic indicator is required but neither a full nor a restricted consumption expenditure measure is plausible.

Table 9.9: Characteristics of SEP indicators

Criteria for SEP indicators	Wealth index	Consumption expenditure	Education	Perceived adequacy of food consumption	Perceived adequacy of consumption	Economic Ladder Question	Perceived income sufficiency	Participatory wealth ranking	Morris' reduced consumption list
1. Ease and cost of data collection	good	poor	good	good	good	good	good	fair	fair
2. Reliability/ reproducibility	fair	poor	good	unknown	unknown	fair	unknown	good	fair
3. Potential for sensitivity	unknown, but likely good	unknown, but likely good	good	unknown	unknown	unknown	unknown	unknown	unknown, but likely good
4. Locally-relevant	poor	good	good	good	good	good	good	good	good
5. Well-understood	poor	good	good	Poor, but potential to explore	fair	fair, and potential to explore further	poor, but potential to explore	good	good
6. Clear policy implications and causal pathways	poor	good	good	fair	poor	fair	fair	fair	good

9.6 Chapter key messages:

1. Agreement of the wealth index with other SEP indicators is generally low, such that using alternative SEP measures results in different conclusions about the socio-economic hierarchy
2. None of the alternative SEP indicators in the Malawi IHS2 data could be considered an accurate proxy for consumption expenditure, although the ELQ has stronger agreement than the wealth index and other SEP indicators considered
3. Subjective SEP indicators that can be captured with a single question appear to have similar relationships to education and consumption expenditure to the wealth index, but are not strongly influenced by community infrastructure in the way that the wealth index is
4. The proportion of variance explained by the key SEP indicators education and consumption expenditure is lower for subjective SEP indicators than for the wealth index

9.7 Next steps

In this chapter, I have identified some potential alternatives to the wealth index, quantified their agreement with the wealth index, and in some cases explored the socio-economic processes underlying those indicators. The next step is to compare the consequences of using the wealth index or one of these alternative SEP indicators. In **Chapter 10**, I consider some of the different situations whereby SEP indicators are used: quantifying inequalities, understanding the determinants of health, controlling for confounding, and targeting of programs/interventions. For each of these uses, I explore the consequences of using either the wealth index or the potential alternative measures.

10. The wealth index versus alternative SEP indicators

In this chapter I explore the consequences of using the wealth index or the alternative SEP indicators that are available in the Malawi IHS2 data. I consider four different situations in epidemiological research when a wealth index might be used: quantifying inequalities, exploring the determinants of health, controlling for confounding by SEP, and program/intervention targeting. In each case, I compare the results when using a wealth index with the results using alternative SEP indicators. I focus on using the wealth index within epidemiological studies of child health in low- and middle-income countries, with stunting as the example of a child health indicator.

10.1 Objective & hypothesis

The overall objective of this chapter is:

- To explore the consequences of using the wealth index or potential alternative SEP indicators

Specific objectives will be detailed in each section.

My main hypothesis is:

1. The consequences of choosing the wealth index or one of the potential alternative SEP indicators will differ depending on the purpose for which the indicator is being used; the difference may be least for quantifying health inequalities

10.2 Chapter approach

In this chapter, I compare the consequences of using the wealth index with other SEP indicators. I focus on SEP indicators as they are frequently used in epidemiological studies in low- and middle-income countries. The literature review in **Section 1.8** demonstrated that wealth indices are commonly used for quantifying inequalities, exploring the determinants of a health outcome, and controlling for the confounding effects of SEP. I will explore each of these uses in turn, comparing results when a wealth index is used with when alternative measures of SEP are used. I also include the use of a wealth index for program/intervention targeting; for instance if a policy or research intervention is to be directed at the poorest members of a community. In these analyses, I concentrate on studies of child health, using stunting as an example measure of child health. Stunting refers to low height-for-age. It was chosen as the measure of health for this analysis because it is widely held to be a good general indicator of overall child health and is strongly determined by living conditions.[337] It has been used by economic historians, development economists and others as an indicator of living standards.[333, 338, 339] Adult height is strongly related to height-for-age in childhood[340], and is predictive of mortality and a wide range of morbidities, particularly cardio-vascular disease.[341-347] Height is thought to represent childhood conditions, with positive conditions increasing height primarily through increased leg length.[348, 349]

10.3 Nutritional status and its measurement

This section outlines height-for-age, or stunting, as a measure of child health. Its measurement and determinants are described, as are the reasons why an association between SEP and stunting would be expected in most populations. The determinants of stunting are used later in this chapter to identify potential predictors of missingness of height data.

10.3.1 Malnutrition and health

Malnutrition is a general term referring to the condition that arises when the body does not get the right amount of nutrients. It can result from either inadequate food consumption or use/excretion of nutrients that is faster than the replacement rate.

Malnutrition has severe repercussions for child health and survival; it is implicated in more than half of the world's deaths in children under five years.[350] Famine, war, and other acute crises make up only a very small part of the burden of malnutrition, which is largely a long-term ongoing problem. Most of the deaths associated with malnutrition are from mild to moderate malnutrition rather than severe immediately life-threatening forms such as kwashiorkor or marasmus.

Children who are malnourished are more likely to get ill and more likely to die when they are ill. Malnutrition and illness have a bidirectional relationship, with each frequently resulting from the other. For instance, malaria is estimated to be the cause of approximately one third of child malnutrition, and diarrhoeal dehydration, a leading child killer, is often aggravated by malnutrition.[350] Malnutrition is thought to lead to disease by causing an impaired immune system which diminishes the child's ability to resist infection and recover from illnesses. Illness is thought to lead to malnutrition primarily through impairing the absorption of nutrients.[351]

Malnutrition has also been associated with adverse consequences for child development[352], educational attainment[353], and lower physical and intellectual productivity in adult life.[354] There is also growing evidence of life-course effects of early nutrition, i.e. poor nutrition and feeding practices in early life can increase the risk of chronic diseases in adulthood.[355-357]

10.3.2 Anthropometry

Anthropometry is the science of measuring people; it involves the measurement of outward physical dimensions using specialised equipment (for a review see [358]). Anthropometric measures and indices can be used as proxies of nutritional status, and are also used as general indicators of health because of the strong relationship between nutritional status and health.

Anthropometric measurements can be performed relatively quickly, easily, and reliably using portable equipment. They are therefore ideally suited to large-scale studies with a limited amount of resources available to dedicate to measurement of health outcomes. The most common anthropometrical measures included in large-scale studies are height and weight. Height-for-age is the outcome being used in this thesis. Standing height is measured in children over two years old, whereas recumbent length is measured in younger children. Length is approximately 0.7 cm greater than height.[359]

10.3.3 Height-for-age and stunting

Height-for-age is a measure of achieved linear growth; height is compared with the median value in a reference population for a given age and sex. Low height-for-age is referred to as 'shortness' and may either be the result of a normal (genetic) variation in height or of a pathological process resulting in failure to reach linear growth potential (stunting). Stunting is the result of long-term and cumulative circumstances; it can result from extended periods of inadequate food intake, poor dietary quality, ill-health, or a combination of these factors. Height-for-age is therefore used as an indication of past chronic nutritional status or poor health.

The prevalence of low height-for-age is generally highest in countries with poor economic conditions, and in these settings children with low height-for-age can mostly be assumed to be stunted. In contrast, in settings with a low prevalence of low height-for-age, these children will mostly be genetically short.[360]

The prevalence of low height-for-age is generally highest in children aged 2-3 years, since the causes of stunting are long-term and it takes some time to develop. In some settings, however, a deficit in length-for-age can manifest as early as the first 3-6 months of life.

Height-for-age has been shown in several settings to be highly predictive of child mortality, morbidity and child development.(Reviews[351, 352])

10.3.4 Comparisons with a reference population

An individual child's anthropometric index can be compared with a reference or standard population using a z-score. Standard populations are based on individuals experiencing favourable conditions for the outcome, whereas reference populations do not necessarily restrict themselves to individuals living under favourable conditions.

Z-scores are used as a means of comparing where an individual measurement falls with respect to the reference/standard population. For child *i*, the z-score is defined as:

$$Z_i = \frac{AI_i - MAI}{\sigma}$$

where AI is the anthropometrical index and MAI is the median of the reference/standard population. Assuming the z-scores are normally distributed, a z-score of less than -2 is usually taken to represent moderate undernutrition and a z-score of less than -3 is taken to represent severe undernutrition.

The WHO Multicentre Growth Reference Study

The WHO Multicentre Growth Reference Study (MGRS) was implemented between 1997-2003 with the intention of establishing standards for growth of children after a review had found important limitations with the National Centre for Health Statistics (NCHS)/WHO international reference, which had been the most commonly used standard.[361, 362] The WHO recommend that the new MGRS reference should now be used due to its advantages over the NCHS standard[363], although concern has been expressed about the consequences for using the new methodology for targeting of child nutrition programmes.[364] Prevalence of malnutrition tends to be higher when using the MGRS compared with the NCHS, but inequalities in stunting and wasting have been shown to be similar using the two methods.[365]

For the MGRS, children were recruited from a diverse set of countries: Brazil, Ghana, India, Norway, Oman and the USA. Data was collected longitudinally for children aged 0-24 months and cross-sectionally for children aged 18-71 months. All children in the study were healthy and living under conditions likely to enable achievement of their full genetic growth potential.[366] In addition to screening mother-child pairs for eligibility, breastfeeding was encouraged and monitored through frequent visits from trained lactation counsellors,[367] and the children's intake of complementary foods was monitored to ensure their diet conformed to global recommendations and was sufficient to support growth.[368] Thus this study has produced 'standards' rather than a reference; it defines how children should grow, which was shown to be remarkably similar in all of the diverse study settings.[369] Percentile (99^{th} – 1^{st}) and z-score (+3 to -3 standard deviations) curves were generated separately by sex and age; length/height-for-age follows a normal distribution whereas for other indices skewness was included in the models.[370] A single model was fitted for each of length/height-for-age and weight-for-length/height, by calculating and allowing for the difference between length and height.[359]

10.3.5 Inequalities in nutritional status

In the overview report of inequalities in DHS datasets from 56 countries, the wealth index was associated with stunting in every country for which anthropometry data was available[58], indicating that the wealth index, or rather the underlying concept that it is capturing, is clearly an important determinant of stunting. Many studies have shown that various measures of low SEP are associated with stunting.[371-382] In order to appreciate why inequalities in stunting arise, it is important to understand the determinants of nutritional status.

It is established that the proximal determinants of under-nutrition are inadequate dietary intake and disease (incidence, severity, and duration), but in addition to these physiological causes, there is a complex web of social, cultural, economic and political determinants. These underlying causes operate at individual, household, community, and national levels.[350]

UNICEF have developed a conceptual framework of the determinants of malnutrition.[350] This conceptual framework, as presented in **Figure 10.1**, defines three levels of determinants: immediate, underlying and basic. This framework is widely used as the basis for epidemiological analyses of the determinants of nutritional status.

Immediate determinants identified by UNICEF are inadequate dietary intake and illness. Malnutrition compromises the immune system, resulting in more frequent, more severe, and longer duration of illness. Furthermore, illness can result in malnutrition, since ill-health can cause loss of appetite, and malabsorption of nutrients.[373, 378, 381, 383-387]

Underlying determinants are factors that lead to inadequate dietary intake and infectious disease: inadequate access to food, insufficient health services and an 'unhealthful' environment and inadequate care for women and children.

Inadequate access to food can result from a lack of household food security (sustainable access to a sufficient quantity of food that is safe and of adequate quality). In rural areas, food security may be dependent on having the resources to ensure sufficient home production (i.e. ownership of/access to land, etc). It may also be affected by seasonal variations in food production, and by environmental conditions. In urban areas, food is mainly bought at markets so food security may be less of an issue, or may be affected mainly by sufficient income to purchase food. Access to food is not determined solely by food availability; it also depends on financial, physical, social, and political limitations to access. Food prices may vary for both sellers and buyers for reasons outside of their control.

Poor health services, unsafe water and lack of sanitation facilities are all underlying determinants of malnutrition.[373, 374, 376, 378, 385, 386, 388, 389] Effective healthcare can reduce the incidence, severity and duration of infectious diseases, which in turn can reduce the burden of malnutrition. Furthermore, health providers may detect and treat malnutrition itself. Important factors to do with health services include: distance to nearest health facility, accessibility, qualifications of staff, equipment, affordability, etc. Environmental health factors that affect malnutrition include clean water, adequate sanitation facilities, hygienic handling of food; lack of these things can lead to diarrhoea and an increased spread of other infectious diseases, thereby increasing the burden of malnutrition. A further link between malnutrition and water supply is that women and children are usually responsible for fetching water; the further away the water source is, the more calories this activity consumes.

Care practices that can affect malnutrition include feeding practices, as well as other care behaviours that affect the way available food and health services are utilised in order to provide nutrition and a good environment for child growth and development. Important feeding practices include breastfeeding (timing of initiation, exclusive, duration); appropriate, correctly timed, and hygienic complementary foods[383]; sufficient quantity and frequency of food, and cultural factors such as whether children are fed first or last in the family, and whether women and girls are fed after men and boys. Health-seeking behaviours such as immunisations and other preventative care can reduce the burden of malnutrition, as can early and good quality treatment for illnesses.[374, 380, 385] Other care practices that encourage good child development can also affect nutritional status; e.g. there is evidence to suggest that the adverse effect of malnutrition on growth can be attenuated if children are given verbal and cognitive stimulation.(cited in [350]). The status and care of women can also affect child nutrition; for instance women who are released from heavy labour during pregnancy are less likely to have low birth weight infants. Attitudes and status have been shown to influence child nutrition. For instance, maternal influence over her child's feeding patterns is positively associated with nutritional status, as is her general satisfaction with life and willingness to seek help when the child is sick.[371]

Maternal education is one very important underlying cause of child malnutrition. There is a substantial body of evidence showing that low maternal education is associated with wasting and stunting in children.[337, 372-374, 376, 380, 382, 384-386] There are several pathways through which maternal education could affect child nutrition. Firstly, it may be acting as a proxy for individual SEP and/or characteristics of the community such as higher quality health services, clean water, and improved sanitation services. More highly educated women are more likely to live in areas with these services. There has been some suggestion that maternal education may have a direct influence on health-seeking behaviour, but little causal relationship with actual health outcomes such as height-for-age.[390] However, if maternal education affects health-seeking behaviours such as immunisation, it is likely to have an impact on the child's height-for-age and weight-for-height due to the nature of the relationship between infection and malnutrition. Maternal education may also affect care practices, through increasing knowledge of the nutritional value of foods, breastfeeding, etc, and therefore improving feeding patterns of the child. Higher levels of maternal education within a society may be an indication of women having higher status and empowerment and suffering from less discrimination, all of which may benefit child nutrition. It is also noteworthy that stunted children whose mothers have low education levels have a lower chance of recovery from stunting compared with children whose mothers are more educated.[337]

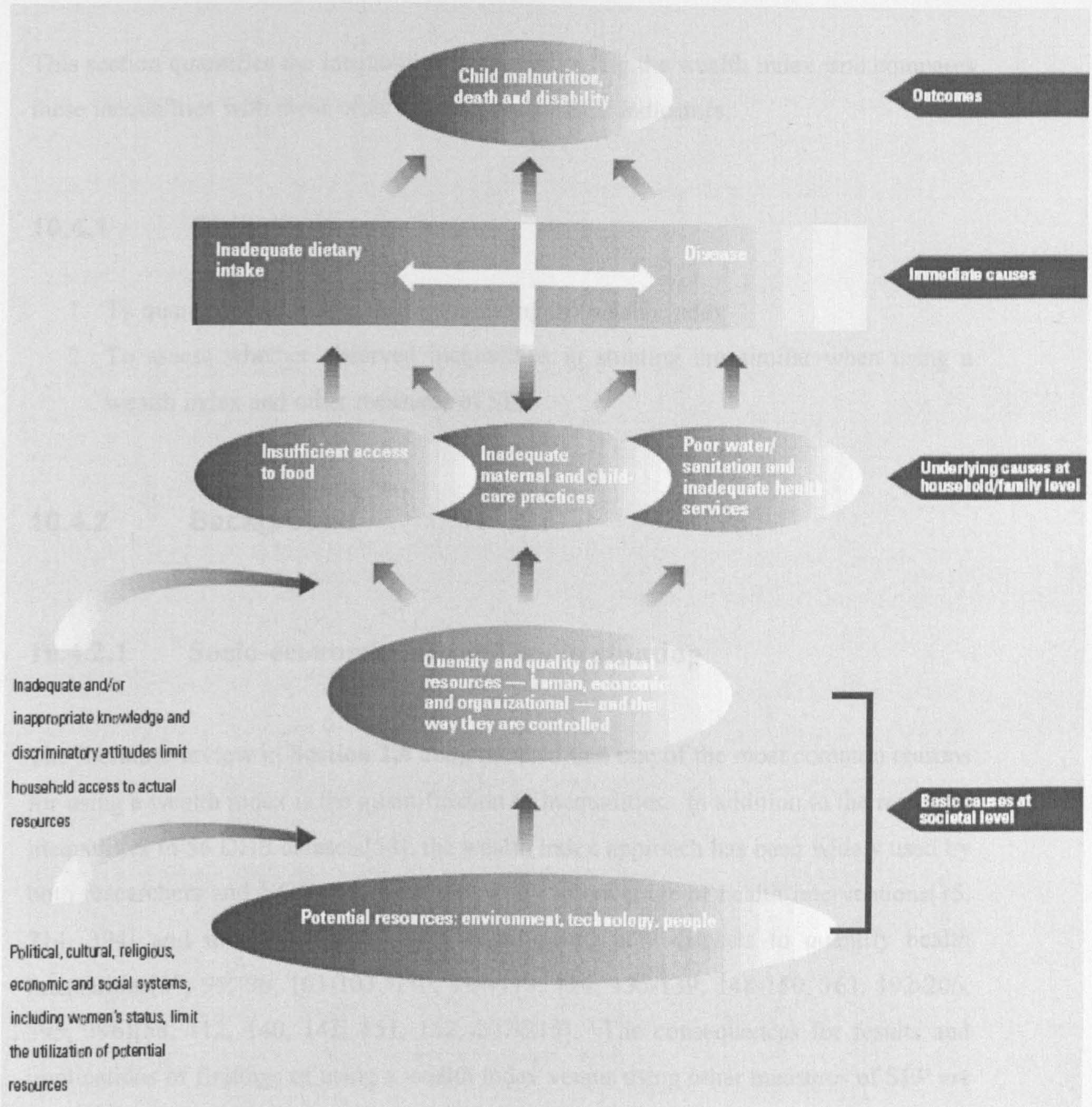
Urban/rural residence is an important underlying determinant of nutritional status. Rural children are generally at higher risk of stunting.[376, 380, 382, 383, 391] Urban areas have better health services, and there is more chance of having clean water and sanitation facilities, which reduce the risk of infection. Urban residents are less likely to be subsistence farmers, so may have higher food security and a more varied diet. In some settings, however, larger socio-economic inequalities in stunting have been demonstrated in urban areas compared with rural areas, due to greater social diversity between groups living in urban areas and relative heterogeneity amongst rural populations.[375] The risk factors for stunting and wasting can be different in urban and rural areas.[392] Living in an area with harsh environmental/weather conditions has also been shown to be associated with stunting.[374] Area of residence (urban or rural) can also modify the effect of various other risk factors for both stunting and wasting.[379]

Basic determinants of malnutrition identified by UNICEF are social, political, economic, and cultural systems. Poverty is often cited as the root cause of malnutrition, but although it plays a clear and crucial role, poverty is not the only basic cause. Political, legal and cultural factors may present barriers to good nutrition. For example, they may influence the rights and protection of women and children, and therefore the ability of women to influence their children's nutrition. The cycle of poor nutrition is intergenerational; girls with poor growth become stunted women, whose babies are more likely to be low birth-weight; if those low birth-weight infants are girls, they are likely to continue the cycle by becoming stunted women.[373, 393]

10.3.6 Socio-economic position and stunting

Socio-economic position, with its broad definition encompassing many aspects of living conditions and life experience, could be expected to be directly and indirectly associated with virtually all of the immediate, underlying, and basic determinants of nutritional status. It is thus unsurprising that many measures of SEP have demonstrated inequalities in stunting in a range of settings. The basic determinants in the UNICEF framework could be hypothesised to also be determinants of the wealth index; for instance political and societal factors could affect the availability and affordability of the indicators used in a wealth index. The indicators used to construct a wealth index could also have direct and indirect relationships with the underlying and immediate causes of malnutrition; e.g. children living in poor quality housing may have greater risk of infections, households who do not own a set of consumer durables may also lack the ability to give their children a sufficient and varied diet. Furthermore, the wealth index itself usually includes water and sanitation facilities, which are specified in the UNICEF conceptual framework as underlying causes of nutritional status.

Figure 10.1: UNICEF Framework of the determinants of nutritional status[350]



10.4 Quantifying inequalities

This section quantifies the inequalities in stunting using the wealth index, and compares these inequalities with those observed using other SEP indicators.

10.4.1 Objectives

1. To quantify inequalities in stunting using the wealth index
2. To assess whether observed inequalities in stunting are similar when using a wealth index and other measures of SEP

10.4.2 Background

10.4.2.1 Socio-economic inequalities in stunting

The literature review in **Section 1.8** demonstrated that one of the most common reasons for using a wealth index is the quantification of inequalities. In addition to the report on inequalities in 56 DHS datasets[58], the wealth index approach has been widely used by both researchers and NGOs to assess the equity of coverage of health interventions[15, 214, 394] and in studies using both existing and new datasets to quantify health inequalities[67, 95, 96, 101-103, 110, 114-118, 124, 135-139, 148-150, 163, 192-206, 395, 396][58, 112, 140, 142, 151, 152, 207-215]. The consequences for results and implications of findings of using a wealth index versus using other measures of SEP are largely unknown. Leaving aside conceptual and other considerations, if the objective of a study is to quantify health inequalities, it could be argued that re-ranking of households between a wealth index and consumption expenditure is irrelevant if the two measures produce similar results in terms of observed inequalities. As Wagstaff & Watanabe point out, even when rank differences between two SEP indicators exist, if these rank differences are not correlated with health, the measured inequality will be the same.[192]

The published literature provides some evidence about the differences in observed inequalities when using a wealth index or a measure of consumption expenditure. Wagstaff & Watanabe demonstrated that in 19 countries, there was on average a 12-14% difference in the concentration indices for stunting and wasting when comparing a wealth index with consumption expenditure.[192] They felt that this difference was small, and that there was sufficient justification for using a wealth index in place of consumption expenditure, given the costs of collecting expenditure data. They also noted that the inequalities tended to be wider when using consumption expenditure than when using a wealth index. In contrast to this finding, Bollen *et al.*[63] and Lindelow[64] both concluded that inequalities (in fertility and health service utilisation respectively) sometimes showed substantial differences, and were generally wider with a wealth index than with consumption expenditure. Filmer & Pritchett noted greater 'wealth effects' on school enrolment when using a wealth index compared to consumption expenditure in two of the three datasets they explored, and an almost identical effect in the third dataset.[29] Sahn & Stifel[67] and Rutstein[56] also showed that inequalities (in child height-for-age and contraceptive-use respectively) were the same or greater by a wealth index than by consumption expenditure, which these authors claim is a reason to use the wealth index in preference over consumption expenditure. The weight of the evidence therefore suggests that inequalities using a wealth index are likely to be similar or larger than when using consumption expenditure. There is, to my knowledge, no evidence regarding the comparative magnitude of inequalities using a wealth index versus other, non-consumption based, measures of SEP.

If the wealth index does result in similar magnitude of inequalities to consumption expenditure, this could be used as justification for using it when expenditure data is not available or would be too costly to collect. This would not, however, remove concerns about the lack of conceptual clarity with a wealth index. If, therefore, inequalities were also similar when using other simple measures of SEP that would perhaps be more conceptually clear than a wealth index, these measures could be considered preferential to a wealth index.

10.4.2.2 Issues in calculating inequalities

Missing data

Whilst levels of missing data for all SEP indicators in the IHS2 dataset are very low, the level of missing data for height is fairly high (14% of eligible children). High levels of missing data are not uncommon in anthropometry, since the child has to be present, well, and co-operative at the time of interview.

Missing data can result in invalid inferences from analyses. Complete-case analysis is only valid if the data are missing completely at random (MCAR). MCAR means that the mechanism by which data become missing is not related to any observed or unobserved factors. This possibility is extremely unlikely to arise since there are likely to be non-random reasons for children not being measured; e.g. those who are sick, those who are not present at the time of the interview due to being taken to the fields with their mother, and so on. The other two options for the mechanism of missingness are missing at random (MAR) and not missing at random (NMAR). MAR means that the missingness mechanism depends on observed data, but not on unobserved data. NMAR means that missingness depends on unobserved data, even after allowing for any dependence on observed data. It is not possible to empirically determine the missingness mechanism.

Multiple imputation is one method for dealing with missing data, which was developed by Rubin.[397] It is considered preferable to methods such as last observation carried forward or mean imputation, which can increase rather than decrease bias.[398-400] Observed data are used to learn about the relationships between variables, and therefore guide the imputation of missing data. In the simplified example of a dataset only having two variables, Y_1 which is completely observed, and Y_2 which is partially observed, the missing values of Y_2 are drawn from the distribution of $Y_2|Y_1$. The imputations are run K times (typically K=five), creating a separate complete dataset each time; each dataset is then analysed separately to yield a parameter estimate, Qk. The values of Q for each imputed dataset are combined; the mean is estimated from the average of the estimates from each of the imputed datasets, and the variance is estimated using both between- and within-imputation components of variance. Mathematical formulae and explanations of the rationale behind combining the estimates can be found on the Missing Data website.[401] Multiple imputation assumes that data are MAR, an assumption that cannot be empirically verified but that can be explored using sensitivity analysis.

Clustering in households

All analyses in this thesis have accounted for the sampling design of the IHS2, i.e. clustering within sampling strata and unequal sampling probabilities have been adjusted for. In analysis of inequalities in stunting, however, there is also clustering of children within households. There may be multiple children aged between six and sixty months in a single household. Children from a single household will automatically have the same wealth index score. They are also likely to share genetic, social, environmental, and health factors that will affect their risk of stunting. I will explore the extent to which this additional level of clustering affects estimated inequalities by carrying out analysis with and without adjustment for within-household clustering.

10.4.3 Methods

Initially, I quantify the inequalities in stunting using the wealth index, explaining and exploring some of the issues in this analysis. Subsequently, I go on to quantify and compare the inequalities in stunting using the range of SEP indicators available in the IHS2 data.

10.4.3.1 Measuring stunting

Height-for-age z-scores were calculated using the Stata macros accompanying the WHO Multicentre Growth Reference Study.[363] Stunting was defined as a z-score of -2 or less.

10.4.3.2 Age of children

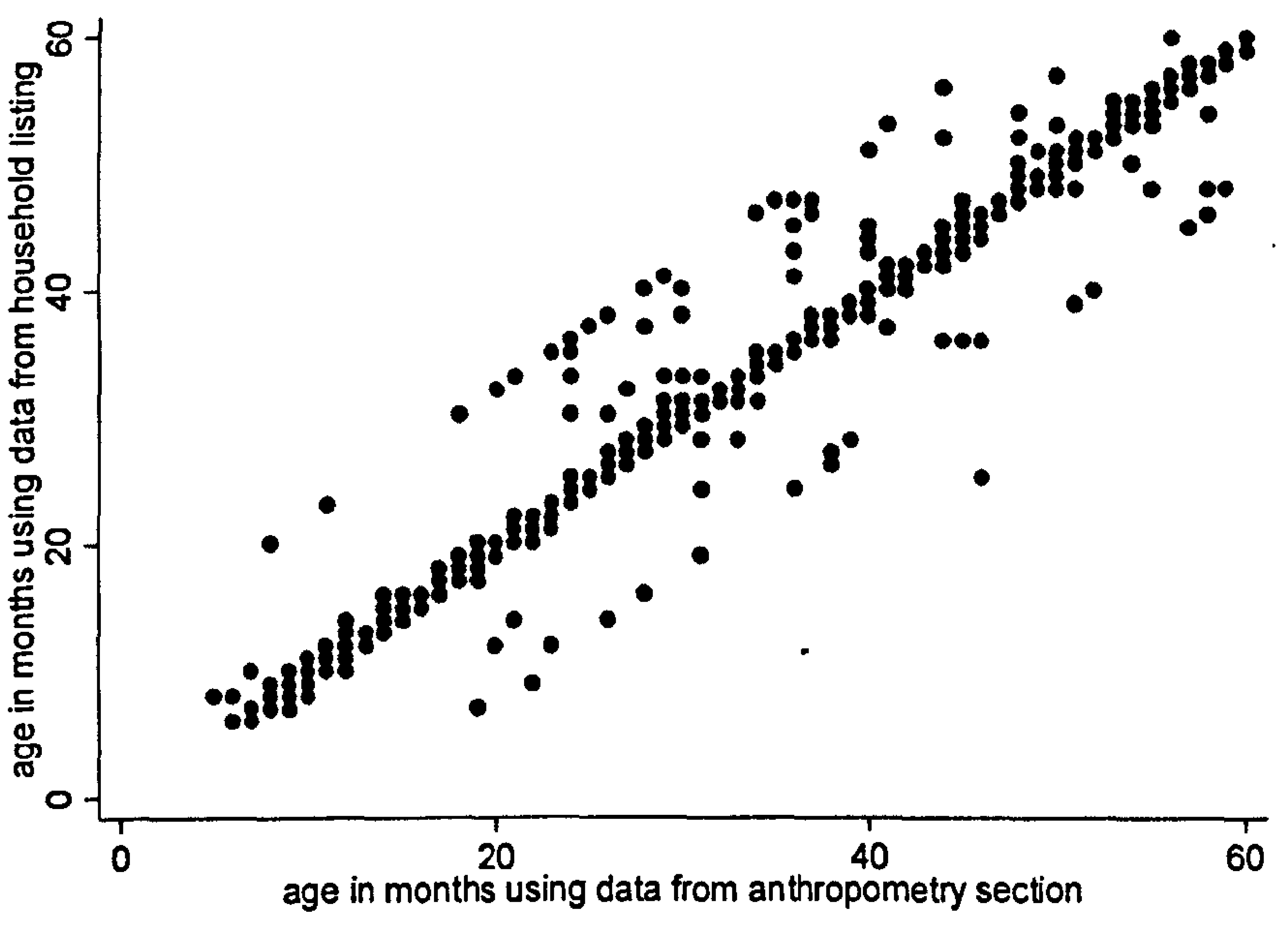
One important limitation in the process of calculating height-for-age z scores is that z-scores should be calculated using exact ages (in days), but the available age data in the IHS2 is completed months of age; calculated z-scores will therefore have some degree of inaccuracy.

Under the IHS2 protocol, anthropometry data (height/length, weight, and presence of oedema) were to be collected on children aged between 6-60 months. The age of all household members is reported by the head of household and recorded in the household listing at the start of the questionnaire. Additionally, in the anthropometry section of the survey, the ages of children for whom anthropometry data were or should have been collected are recorded. The age in this section is likely to have been reported by the main caregiver of the child, and the enumerator manual states that this age is expected to be more accurate than that provided by the head of the household. Interviewers were instructed to take particular care in ascertaining children's ages, asking to see child immunisation records or similar documents which may have a record of the date of birth, and making use of a national calendar of events to aid memory.

There are some differences in the ages recorded by the head of household and in the anthropometry section of the questionnaire (**Figure 10.2**). In the majority of cases, the recorded ages are the same or similar.

In cases where the difference between the two ages was less than one year, z-scores calculated using each age were examined. In the vast majority of cases, the age provided by the main caregiver was accepted since this individual may be more likely to know the child's age than the head of the household, and the interviewer's manual indicates that this age is perhaps more likely to have been verified against immunisation records etc. However, in two cases the age provided by the main caregiver gave z-scores which were not biologically plausible (height-for-age z-score >|6|) and the z-scores for the age provided by the head of household were biologically plausible. In these two cases the age values provided by the head of household in the household listing were accepted.

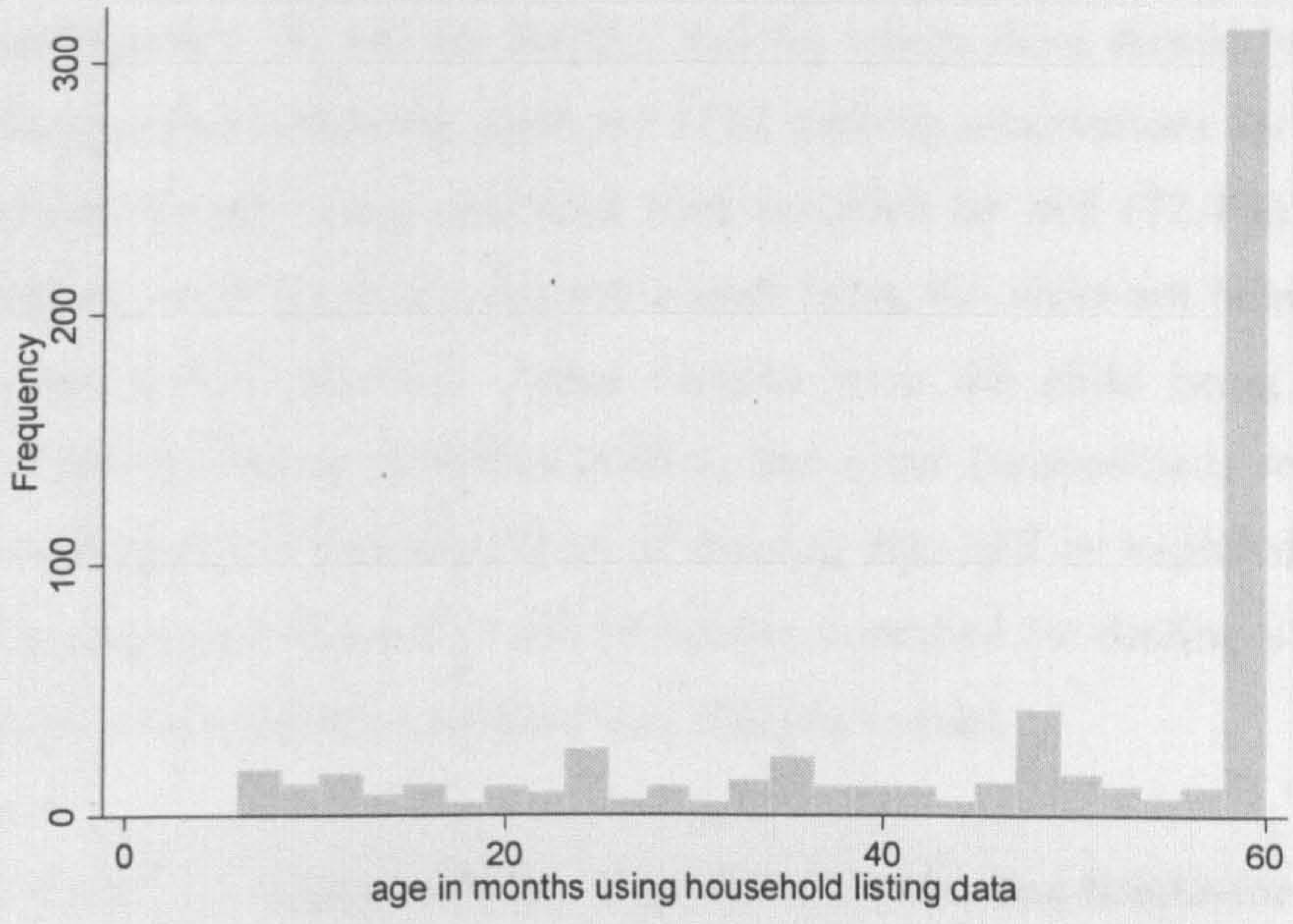
Figure 10.2: Differences between ages recorded in the household listing and in the anthropometry section



In the small number of cases (33) where the difference between the ages was 12 months or more, the anthropometry data were examined; in each case one age produced an extremely unlikely anthropometric value (i.e. z-scores of a magnitude greater than 5). In these cases, the correct age was assumed to be the age resulting in plausible anthropometric data, and the assumed incurred age was recoded to match the assumed correct age. In most cases, these mistakes appeared to have arisen due to apparent questionnaire completion or data entry mistakes; for instance, months being recorded as years and vice versa.

There are 628 individuals whose age is listed in the household listing as between six and sixty months, but who do not have any age recorded in the anthropometry section. For all of these 628 individuals, the adult-only sections of the questionnaire are not completed, suggesting that they are children. In 59 of these 628 cases, anthropometry data has been recorded, suggesting that the child was believed to be in the correct age range, but that age has not been recorded in the anthropometry section - perhaps because of a simple omission or perhaps because the adult respondent did not know the child's age. In these 59 cases, the age recorded in the household listing has been assumed to be correct, since this is the best available estimate and produced plausible z-scores. Of the remaining 569 individuals, the vast majority (298) are recorded as 60 months in the household listing (**Figure 10.3**). In these cases it can be fairly safely assumed that the child's caregiver reported in the anthropometry section that the child was over 60 months of age. As such, the individuals were assumed to be not eligible for anthropometry data collection, and were not counted as missing data. For consistency, the seven children recorded in the household listing as being six months old were also assumed to be less than six months old, and were also not counted as missing data. It is not clear, however, why the age and anthropometry data were missing for the remaining 264 individuals, whose reported ages were fairly evenly spread between seven and 59 months in the household listing. For these 264 individuals, the age reported in the household listing was assumed to be correct as it is the best available estimate of age, and the anthropometry data were assumed to be missing.

Figure 10.3: Distribution of ages of individuals reported in the household listing as being between 6-60 months, but for whom the age data in the anthropometry section was missing



10.4.3.3 Calculating inequalities in stunting

The relationship between stunting and quintiles of the wealth index was quantified by i) cross-tabulation and ii) the relative index of inequality (RII). The relative index of inequality is a measure of inequality based on household rankings. A variable of socio-economic rank is created, equal to the proportion of households with a higher position in the wealth index hierarchy than the mid-point of each wealth group (quintile); the rank variable thus takes possible values of between zero and one. The RII is the coefficient from a logistic regression on stunting of this rank variable (treated as a continuous variable in the logistic regression).[24, 402-404] The interpretation of the RII is the odds predicted at the lowest point in the wealth hierarchy divided by the odds predicted at the highest point of the wealth hierarchy. The larger the RII, the greater the degree of inequality across the socio-economic hierarchy.

10.4.3.4 Amount of missing height data and reported reasons for missingness

There are 7936 children who, according to the best available estimate of their age, are aged between six and 60 months, and for whom there should be anthropometry data. Amongst these children, there are 1112 missing observations for height (14.0%). The reasons for not being measured were recorded for 805 (72.4%) of the non-measured children, with the most common reason being the child not being at home during the survey period (60.1%). Other reasons were the child being too ill (16.3%), the child/parent being unwilling (4.6%), and other (unspecified) reasons (19.0%). The consequences of this high level of missing data will be explored later in this chapter, when multiple imputation will be used as a method for dealing with missing data. For these initial analyses, complete case analysis is used.

10.4.3.5 Using multiple imputation for missing height-for-age data

The first step in multiple imputation is to assess the pattern of missingness. Predictors of missingness of height were explored using univariable methods (t-tests or chi^2 tests). Variables explored as potential predictors of missingness were those identified from the UNICEF conceptual framework (Figure 1) as determinants of height-for-age, and any other variables considered likely to affect a child's probability of being measured (such as overall 'success rate' of the interviewer or month of interview).

Variables that were associated with the missing value indicator with a p value of <0.10 were put into a multivariable model. Predictors of missingness were retained in the final multivariable model if they had a p value of <0.10. This significance level was used in preference to a 5% statistical level following advice that including fairly weak predictors of missingness does not introduce substantial bias to imputations.[405]

The MLwiN multiple imputation program can cope with multilevel data (i.e. it could allow for the effects of the sampling structure in IHS2). In these analyses, however, height is being imputed, and height-for-age z-scores must be calculated from the height data using the WHO multicentre growth reference study macro in order to proceed with analyses. This would not be possible with MLwiN, and so the chain equation method (`ice` command) in Stata 10 was used to carry out the multiple imputation. Although ignoring the multilevel structure of data can result in bias when using multiple imputation, this is considered unlikely in this case since the clustering appears to make little difference to analyses (survey and simple analyses produce extremely similar results).

The imputation model was set up, with the core wealth index and the predictors of missingness of height as determined from the multivariable model. Multiple imputation in Stata produces unreliable results if categorical data are used; therefore dummy variables were created for categorical variables and used in the imputation model. 5 sets of imputations were run, and the relative index of inequality was calculated by combining these datasets using the `micombine` command in Stata.

Previously, the RII was calculated using logistic regression using the survey commands of Stata to allow for the clustered sampling. The survey commands are not compatable with multiple imputation post-estimation. Generalised estimating equations (GEE) were therefore used instead of the survey commands. GEEs are population averaged models, which can be set up to recognise the clustered nature of data and consider both within and between cluster variance. The `xtgee` command in Stata was used, with the dataset being `xtset` to specify that the data were clustered around strata. Household sampling weights were specified, and the Bernoulli/Binomial family and the correlation structure was assumed to be equal correlation (exchangeable). Specifying the correlation structure as independent, whereby clustering is only taken into consideration in the variance and not in calculation of the parameter estimate did not substantially alter the estimate from when an exchangeable correlation structure was specified. Robust standard errors were used to correct the standard error for the effect of clustering. Robust standard errors use the Huber/White sandwich estimate of variance. They are based on the data rather than on a full probability model, and are therefore useful in situations where a full probability model is not available, such as with multistage sampling. The GEE model to calculate the RII was initially run on the original complete-case data, in order to ensure that it produces similar results to the survey analysis. Subsequently, it was run on the imputed datasets.

10.4.3.6 Adjustment for clustering within households

In order to calculate the RII adjusted for clustering both due to sampling strata and multiple children per household, logit models were run in MLwiN 2.02. Two models were run and compared: i) adjusting for clustering due to sampling strata, and ii) adjusting for clustering due to both sampling strata and households. Models were run only on the 6683 children with complete data for both the wealth index and height-for-age.

10.4.3.7 Inequalities in stunting using multiple SEP indicators

Inequalities in stunting were calculated using six hierarchical measures of SEP available in IHS2: the wealth index, per capita consumption expenditure, education of the household head, a measure of perceived adequacy of consumption (of food, clothing, housing, and healthcare), the perceived adequacy of household food consumption, economic ladder question, and subjective income sufficiency.

Quintiles of the core wealth index were used, as defined in **Section 4.3**. The per capita consumption expenditure measure was also as defined previously, in **Section 2.1.4.2**, and was also used in quintiles.

Education of the household head, food consumption adequacy, the economic ladder question, and subjective income sufficiency were used as defined in **Section 7.4**, and quintiles of the consumption adequacy score generated using PCA with polychoric correlations was used as defined in **Section 9.3.2**. Analyses were restricted to those individuals aged between 6-60 months with non-missing height-for-age data and the SEP indicator in question.

The prevalence of stunting across groups of each SEP indicator was calculated, and chi squared tests for trend were performed. Inequalities were quantified using a relative index of inequality (RII). The measures of SEP are on different scales and have different group sizes. The RII is specifically designed to deal with different group sizes, since it uses the socio-economic rank, i.e. the proportion of households with a higher position in the socio-economic hierarchy.[406] The RIIs for each measure of SEP are, therefore, comparable.

If the relationship between the wealth index and stunting is non-linear, the appropriateness of the RII to quantify the inequality is questionable.[403, 404] To assess this, logistic regression models were run to calculate the inequality in stunting both treating the SEP indicators as linear terms and as categorical terms. The models were compared using likelihood ratio tests (LRTs). The reported ORs use survey analysis, but the LRTs were calculated from models using standard regressions that ignored the sampling, since survey analysis is not compatible with LRTs; ORs calculated with and without survey analysis were extremely similar so this is not thought to have introduced substantial bias.

10.4.4 Results

10.4.4.1 Inequalities in stunting using the wealth index

The overall prevalence of stunting is high (approximately 40%), with prevalence being highest in rural areas and lowest in peri-urban areas. The prevalence of stunting is generally similar across the lower four quintiles of the wealth index, with a sharp drop in prevalence in the highest quintile (**Table 10.1**). The lowest 80% of the population in terms of the wealth distribution therefore seem to be at similar risk of stunting, with the top quintile having some degree of protection. The highest quintile of the wealth distribution still has a high prevalence of stunting (approximately 35%). The relative index of inequality is 1.41 in the whole population, such that children from households at the lowest point in the wealth index hierarchy have 1.4 times the odds of being stunted compared with those at the top of the wealth index hierarchy. A similar picture is seen across all areas, but inequalities in stunting are not statistically significant in urban and peri-urban areas, perhaps because of the smaller sample size in these areas. These patterns are very similar to those demonstrated in the 2000 DHS in Malawi.[290]

Table 10.1: Prevalence of stunting overall and by quintile of the core wealth index, and the relative index of inequality in stunting

Percentage of children aged 6-60 months who are stunted	Whole population (n=6748)	Urban areas (n=717)	Peri-urban areas (n=385)	Rural areas (n=5646)
Overall	43.7	39.8	35.5	44.7
Highest quintile	36.5	37.8	34.9	35.4
4th quintile	42.3	50.9	31.9	42.5
3rd quintile	51.1	52.0	50.2	51.1
2nd quintile	44.9	36.2	42.8	45.1
Lowest quintile	44.9	47.5	33.1	45.3
p value from chi^2 test	*<0.001*	*0.26*	*0.59*	*0.0002*
RII (95% CI)	1.41 (1.15-1.74)	1.74 (0.89-3.37)	1.15 (0.53-2.48)	1.30 (1.02-1.65)

10.4.2.2 Using multiple imputation for missing height-for-age data

Factors predictive of missingness

A wide range of potential predictors of missingess were explored (**Table 10.2**), and a number of these were found to be important (p<0.10) and were explored in the multivariable model. The final multivariable model is shown in **Table 10.3**. In the adjusted model, the following factors are predictors of missingness of height data: interviewer having a low overall success rate with anthropometry; being from an agricultural household; child not being usually feverish; urban residence; living in the Centre or South region, and having fewer of siblings.

Table 10.2: Associations with missingness of anthropometry data

A. Continuous variables and their association with missingness of height data

Variable	*Mean (SD)* Height data present	Height data missing	*p value from t-test*
Age (months)	31.6 (15.6)	32.7 (16.3)	0.032
Household size (no. people)	5.8 (2.4)	5.5 (2.4)	<0.001
Per capita consumption expenditure (Kwacha)	18410.2 (14504.7)	21128.9 (19209.6)	<0.001
Core wealth index score	-0.0983 (0.839)	0.0254 (0.974)	<0.001
No. land plots owned by household	1.09 (1.08)	1.00 (0.99)	0.0089
Highest education grade achieved by household head	5.2 (4.2)	5.4 (4.6)	0.078
Age of household head (yrs)	37.7 (12.5)	39.2 (13.8)	0.0001
Birth interval (months)	40.9 (22.2)	42.2 (24.4)	0.17
Number of siblings	2.7 (1.6)	2.2 (1.6)	<0.001
Month of interview	6.2 (3.2)	6.4 (3.2)	0.94

B. Discrete variables and their association with missingness of height data

Variable	***Percentage***		***p value from chi-squared test***
	Height data present	**Height data missing**	
Male sex of child	49.2	49.8	0.68
Region			
North	16.2	13.3	
Centre	39.5	46.5	
South	44.3	40.2	<0.001
Area of residence			
Urban	10.5	13.9	
Peri-urban	5.7	8.0	
Rural	83.8	78.2	<0.001
Child has suffered illness or injury in the past two weeks	40.1	39.5	0.72
Child is physically or mentally handicapped	0.91	1.2	0.46
Child suffers from a chronic illness	6.1	5.7	0.67
Child has lost a lot of weight recently	16.9	15.4	0.25
Child is usually feverish	14.1	11.9	0.067
Child has a cough all the time	6.8	5.5	0.12
Child continuously has diarrhoea	5.9	5.7	0.77
Agricultural household	92.1	88.3	<0.001
Marital status of head of the household			
Monogamous married	74.1	74.4	
Polygamous married	12.5	11.2	
Separated	3.1	2.8	
Divorced	4.4	4.2	
Widowed	5.6	7.2	
Never married	0.25	0.27	0.31
Head of household is employed according to ILO definition	96.2	95.4	0.24
Female-headed household	15.5	15.5	0.99

Variable	***Percentage***		***p value from chi-squared test***
	Height data present	**Height data missing**	
Religion			
None	5.5	5.1	
Traditional	0.98	1.8	
Islam	14.0	11.1	
Catholic	18.9	18.5	
CCAP	15.1	15.3	
Anglican	2.7	2.3	
Seventh day/Pentecostal	5.0	5.3	
Revivalist	5.5	3.7	
Other Christian	27.7	31.1	
Other religion	0.32	0.72	
Last church	4.2	5.1	0.001
Language spoken at home			
Chichewa	55.3	60.9	
Nyanja	10.0	10.6	
Yao	9.9	7.8	
Tumbuka	11.6	9.9	
Other	13.2	10.8	0.003
Household head can read one page letter in Chichewa	100	100	-
Household head can write one page letter in Chichewa	69.2	68.5	0.66
Household head can read one page letter in English	38.9	42.3	0.031
Household head can write one page letter in English	33.6	36.4	0.071
Interviewer success rate with anthropometry			
High	32.6	16.0	
Medium	49.4	51.5	
Low	18.0	32.5	<0.001

Table 10.3: Adjusted multivariable model of predictors for missingness of height

	Odds Ratio (95% CI)	*p*
Overall success rate of interviewer		
High	1	
Medium	2.25 (1.84-2.75)	
Low	3.73 (3.01-4.62)	<0.001
Agricultural household	0.75 (0.58-0.96)	0.023
Child usually feverish	0.82 (0.66-1.01)	0.062
Area of residence		
Urban	1	
Periurban	1.14 (0.83-1.58)	
Rural	0.80 (0.63-1.02)	0.012
Region		
North	1	
Centre	1.40 (1.11-1.78)	
South	1.25 (1.00-1.57)	0.016
Number of siblings	0.94 (0.90-0.98)	0.0050

Modelling the Relative Index of Inequality

The GEE method for calculating the RII in stunting produced very similar results to the Stata survey commands, demonstrating that the two methods for allowing for the clustered sampling in IHS2 are equivalent. Following multiple imputation, there was very little change in the estimated inequality in stunting (**Table 10.4**). The RII dropped from 1.43 with complete case analysis to 1.39 following multiple imputation, a reduction of less than 3%, and the confidence intervals were similar. This would imply that the missing height data in IHS2 are not introducing significant bias to estimates of inequalities in stunting.

Table 10.4: Relative Index of Inequality for stunting, calculated with complete case analysis or following multiple imputation

Analysis method	Relative Index of Inequality (95% CI)
Logistic regression using survey commands (complete-case data)	1.41 (1.15-1.74)
GEE (complete-case data)	1.43 (1.09-1.88)
GEE (after multiple imputation)	1.39 (1.10-1.74)

10.4.2.3 Adjustment for clustering within households

Only approximately one quarter of children are from households where more than one child was included in the anthropometry data collection. Adjusting for clustering within households made very little change to the estimated inequalities, the RII and its confidence interval are very similar for i) the model adjusting for clustering due to sampling strata and ii) the model adjusting for clustering both due to sampling strata and households (**Table 10.5**). Since both missing height-for-age data and clustering within households appear to make little difference to the observed inequalities in stunting, comparisons of inequalities using different SEP indicators will ignore these two features of the data in order to simplify the analysis. Subsequent analyses in this section therefore adjusted for sampling design only, and were conducted using complete-case analysis.

Table 10.5: Relative Index of Inequality adjusting for different levels of clustering

Analysis method	Relative Index of Inequality (95% CI)
2-level model (adjusting for clustering within sampling strata)	1.47 (1.21-1.79)
3-level model (adjusting for clustering within sampling strata and households)	1.48 (1.21-1.81)

10.4.2.4 Inequalities in stunting using multiple SEP indicators

All measures of SEP showed higher prevalence of stunting in the lower socio-economic groups (**Table 10.6**).

For the wealth index, consumption expenditure, consumption adequacy, and income sufficiency a clear linear trend was not present across the quintiles. For these four measures, there was a similar prevalence of stunting across the bottom groups, and a lower prevalence in the top (highest SEP) group. Education, adequacy of food consumption, and the economic ladder question did demonstrate clear linear trends in stunting prevalence across the groups.

The RII was statistically significant for all SEP measures apart from consumption expenditure and income sufficiency. The RII for the wealth index was slightly higher than for consumption expenditure, in keeping with the majority of the evidence from the literature.

The RII for the wealth index was similar to the RII for education of the household head and perceived overall household living standards. The RII for perceived adequacy of household food consumption was larger than the other SEP indicators, although the confidence intervals are overlapping. The RII for the overall consumption adequacy measure was intermediate between that for the wealth index and that for the measure of food consumption adequacy, but all confidence intervals were overlapping. The RII for income sufficiency was larger than for the wealth index, but was not statistically significant at the 95% level.

The logistic regressions, as would be expected, produce similar results, with inequalities being smallest for consumption expenditure and largest for food consumption adequacy. The LRTs confirmed that there is evidence against a linear trend for the wealth index, consumption expenditure, quintiles of consumption adequacy, and income sufficiency, as could be expected from the patterns of stunting prevalence across quintiles. LRTs demonstrated no evidence against a linear relationship for education of the household head, food consumption adequacy, or the economic ladder question.

Table 10.6: Comparison of observed inequalities with different SEP indicators

SEP indicator	*% stunted*	*Relative Index of Inequality (95% CI)*	*Odds ratio; SEP indicator treated as categorical (95% CI)*	*Odds ratio; SEP indicator used as linear term (95% CI)*	p value from test of linearity of ORs[7]
Wealth index					
Highest quintile (n=1,129)	36.5	1.41	1	1.08	*<0.001*
4th quintile (n=1,349)	42.3	(1.15-1.74)	1.28 (1.06-1.54)	(1.03-1.12)	
3rd quintile (n=827)	51.1		1.82 (1.47-2.26)		
2nd quintile (n=1,938)	44.9		1.42 (1.19-1.70)		
Lowest quintile (n=1,486)	44.9		1.42 (1.18-1.71)		
Consumption expenditure					
Highest quintile (n=1,011)	39.4	1.19	1	1.04	*0.061*
4th quintile (n=1,367)	44.6	(0.96-1.48)	1.24 (1.03-1.49)	(0.99-1.08)	
3rd quintile (n=1,402)	43.6		1.19 (0.99-1.43)		
2nd quintile (n=1,472)	46.1		1.32 (1.08-1.60)		
Lowest quintile (n=1,496)	43.6		1.19 (0.98-1.45)		
Education of household head					
Higher (n=85)	33.2	1.49	1	1.12	*0.16*
Partial/complete secondary (n=1114)	37.1	(1.20-1.86)	1.19 (0.68-2.07)	(1.06-1.19)	
Complete primary (n=1,029)	43.2		1.53 (0.89-2.63)		
Partial primary (n=3,001)	45.5		1.68 (0.98-2.89)		
None/pre-school (n=1,499)	45.6		1.69 (0.98-2.91)		
Perceived adequacy of household food consumption					
More than adequate (n=497)	36.8	1.75	1	1.26	*0.38*
Just adequate (n=2,427)	40.3	(1.39-2.21)	1.16 (0.90-1.50)	(1.14-1.39)	
Less than adequate (n=3,822)	46.6		1.50 (1.16-1.94)		
Consumption adequacy					
Highest quintile (n=2,299)	36.2	1.55	1	1.09	*0.026*
4th quintile (n=1,093)	42.2	(1.25-1.92)	1.29 (1.05-1.58)	(1.05-1.14)	
3rd quintile (n=1,834)	45.5		1.47 (1.21-1.80)		
2nd quintile (n=1,241)	44.0		1.38 (1.13-1.70)		
Lowest quintile (n=1,296)	46.6		1.54 (1.27-1.86)		
Economic ladder question					
Step 4 or above (top) (n=224)	34.9		1	1.13	*0.53*
Step 3 (n=940)	41.1	1.40	1.30 (0.90-1.88)	(1.05-1.21)	
Step 2 (n=2,791)	43.0	(1.12-1.75)	1.41 (1.00-1.99)		
Step 1 (bottom) (n=2,787)	45.9		1.58 (1.11-2.24)		
Income sufficiency					
Allows you to build savings (N=172)	38.7	1.40	1	1.05	*0.056*
Allows you to save a little (N=734)	43.5	(0.99-1.98)	1.22 (0.81-1.83)	(1.00-1.11)	
Just enough (N=1983)	41.3		1.11 (0.74-1.66)		
Not enough, use savings (N=1003)	44.5		1.27 (0.84-1.91)		
Not enough, must borrow (N=3878)	44.9		1.29 (0.88-1.89)		

[7] From likelihood ratio tests comparing models where the SEP indicator is treated as i) categorical or ii) linear; $p<0.05$ indicates the categorical model has better fit, i.e. there is deviation from linearity

10.4.3 Discussion

10.4.3.1 Issues in estimating the inequalities in stunting

The level of missing data for height is fairly high in the IHS2 (14% of eligible children). It seems, however, that the missing data are not changing the conclusions of analyses, since the RII calculated using complete case analysis was extremely similar to that calculated following multiple imputation. Multiple imputation is valid under MAR, which assumes that all predictors of missingness have been included in the model. It is possible that factors predictive of missingness have been missed. For instance, there is no information about where and by whom the child is cared for, although this could be expected to be very strongly related to factors included in the model such as area of residence and whether the child is from an agricultural household. If a NMAR missingness mechanism is suspected, sensitivity analyses are advised; however, given the similar estimates using complete case analysis and multiple imputation, sensitivity analysis was considered unnecessary in this case.

Adjusting the RII for additional clustering at the household-level also made very little difference to the estimated inequality, signalling that within-household clustering of stunting is minimal in this sample.

10.4.3.2 Inequalities in stunting using the wealth index

There is evidence of socio-economic inequality in stunting using the wealth index within the Malawi IHS2 data. It appears, however, that the prevalence of stunting does not follow a linear trend across quintiles of the wealth index; there is a similar prevalence in the bottom four quintiles and a sharp drop in prevalence in the top quintile. Linear patterns in stunting prevalence across quintiles of the wealth index are observed in many but not all of the middle- and low-income countries included in the work by Gwatkin *et al.* using DHS data.[58] In the DHS work, there is a linear pattern in moderate stunting (height-for-age z-scores between -2 and -3) in all but five of the 23 Asian, Latin American, and Middle-Eastern countries (Cambodia, Uzbekistan, Guatemala, Yemen, and Bangladesh). In the Sub-Saharan African countries with stunting data included in the report, the picture is reversed; 20 of the 27 Sub-Saharan African countries in the report do not demonstrate a linear pattern in moderate stunting across quintiles of the wealth index. Many of these datasets show a similar picture to the Malawi IHS2, i.e. similar prevalence across the bottom four quintiles with a sharp drop in the top quintile.

Given the strong socially-driven aetiology of stunting, and the fact that stunting itself is often used as a proxy for living standards, the high number of countries with a non-linear pattern in stunting across quintiles of the wealth index is surprising. The difference between Sub-Saharan Africa and the other regions is also striking. It suggests that the wealth index is a less strong predictor of stunting in Sub-Saharan Africa than in other regions. If you accept that stunting is a good marker for living standards, then you could extrapolate this argument to say that the wealth index is a weaker marker of living standards in Sub-Saharan Africa than in the other regions. Since Sub-Saharan Africa is generally less economically developed than other regions, this could imply that the wealth index is a weaker marker of living standards in less economically developed areas. The patterns within regions (using the DHS datasets) support this argument, since it is by and large the less economically developed countries within all regions that demonstrate non-linear trends in stunting across quintiles of the wealth index. This finding is consistent with the weaker agreement of the wealth index with consumption expenditure in rural compared with urban areas (**Section 6.4.5.4**) and the tentative finding from the systematic review that agreement appears on average to be higher in middle-income countries compared with low-income countries (**Section 2.3.3.6**).

It is possible that the social processes driving the wealth index are more important determinants of stunting in middle-income countries compared with low-income countries, and that this is the explanation for the lack of a wealth index gradient in stunting in so many of the Sub-Saharan African countries. It is also possible that the standard set of items in a wealth index is unable to differentiate between households at the lower end of the social spectrum in many settings, leading to heterogeneous social groups in the bottom three or four quintiles of the index. Given the urban bias of many of the items commonly included in a wealth index, this is entirely plausible.

A further potential explanation for the lack of a gradient could be that there is a threshold effect; i.e. the socio-economic conditions experienced by those in the bottom four quintiles of the wealth index in Malawi (and other datasets where no linear gradient exists) result in a similar risk of stunting, and it is only those in the top quintile who have sufficiently improved socio-economic conditions to experience a reduced risk of stunting.

10.4.3.3 Inequalities in stunting using multiple SEP indicators

Consistent with most of the published literature, the wealth index demonstrated wider inequalities than consumption expenditure. The difference was fairly small, and confidence intervals for the RIIs were overlapping. The conclusions about the existence of inequality, however, would be different using the two SEP indicators if using traditional significance testing cut-offs, since the RII was statistically significant at the 95% level for the wealth index, but not for consumption expenditure. This demonstrates that even when magnitude of inequalities is broadly similar using the wealth index or consumption expenditure, important differences in conclusions can arise.

The inequalities in stunting are similar regardless of the measure of SEP used. This indicates that if the aim of the study is to estimate the magnitude of socio-economic inequalities, using a measure of education or a measure of perceived SEP may result in similar results to using a wealth index. Although it must of course be stressed that these results are from a single setting only, and may not be generalisable.

The question on perceived adequacy of food consumption demonstrated the strongest inequalities of all the SEP measures. This is unsurprising, since it relates specifically to food consumption, which is a strong proximal determinant of stunting. Reasons for adequacy of food consumption may be varied, but are likely to be strongly socio-economically determined.

It is interesting that stunting does not follow a linear pattern across quintiles of per capita consumption expenditure in IHS2. Consumption expenditure is widely viewed as a reliable measure of economic position, and would be expected to have a strong graded relationship with stunting. As discussed in **Section 10.4.3.2**, it is possible that in Malawi (and other low-income countries demonstrating no gradient across quintiles of consumption and/or the wealth index) there is a threshold effect in the social patterning of stunting. The bottom 80% of the socio-economic spectrum may experience similar socio-economic conditions and risk factors for stunting, and only the top quintile experience sufficiently favourable socio-economic conditions to result in a reduction in stunting risk. However, in contrast to the wealth index and consumption expenditure, there was a strong linear pattern in stunting prevalence across groups of education of the household head, perceived adequacy of household food consumption and the economic ladder question. This indicates that there are socio-economic processes leading to a gradient in stunting prevalence, but that the most important factors for stunting are not being captured by either the wealth index or by consumption expenditure.

Although the wealth index does not demonstrate a clear gradient in stunting prevalence whereas some other SEP measures do, I would not consider this to be a reason for or against using it as a measure of SEP. It may still be capturing some aspects of social stratification, but those which are less important for stunting in some settings. I would argue that a measure of SEP should not be considered a 'better' or 'worse' indicator because of its relationship with health, even when the health outcome in question is stunting, which is believed to be strongly determined by social factors. A measure of SEP should be used because of interest in the specific social stratification processes it is believed to capture. Thus a measure of SEP should be judged by the ability to understand the social processes driving it, and its ease of interpretation and relevancy to policy.

One interesting aspect of the different SEP measures is that those measures that do not force group sizes to be equal (i.e. do not rely on quantiles) certainly do not result in equal group sizes. Education of the household head, the economic ladder question, perceived adequacy of food consumption, and subjective income sufficiency all have markedly skewed distributions, with the vast majority of households in the lower SEP categories. For instance, 45% of household heads place their household on the bottom of the six steps of the ELQ. It may be the case, therefore, that the lower quintiles of consumption expenditure and the wealth index are not 'natural' groups, in that they do not share common circumstances that are important for stunting in this population.

10.5 Exploring the determinants of health

10.5.1 Background

Another common use of the wealth index is the exploration of the determinants of an outcome (**Section 1.8**). In one fifth of the studies included in the literature review in **Section 1.8** that were exploring the determinants of an outcome, one fifth used the wealth index as the only measure of SEP. Given that the socio-economic processes being captured by a wealth index remain largely unclear, and represent a mixture of household- and community-level effects (**Chapter 8**), its use in studies of the determinants of health is perhaps questionable. If it is to be used in this way, it seems likely that using it as part of a set of SEP indicators would be more appropriate that using it alone. To investigate this, however, I explore in this section whether the wealth index is associated with height-for-age independently of the other SEP indicators, or whether controlling for one SEP indicator attenuates the effect of the others. If the wealth index remains independently associated with height-for-age independently of the effects of the other SEP indicators, this implies it is capturing socio-economic processes that are important for height-for-age but that are not captured by the other SEP indicators.

10.5.2 Objectives

1. Explore whether the wealth index is associated with height-for-age independently of alternative SEP indicators

10.5.3 Hypotheses

1. Given the low R^2 value in models of determinants of the wealth index (**Section 8.6**), I would expect the wealth index to be associated with height-for-age independently of other SEP indicators
2. Given the difference in determinants of the SEP indicators (**Section 9.4**), I would expect each of these SEP indicators to be independently associated with height-for-age

10.5.4 Methods

Path analytic models were run in Mplus version 5 to explore whether the wealth index is associated with height-for-age independently of the other SEP indicators. This methodology was chosen in preference over entering all SEP indicators into a multiple regression model, since path analysis permits assumptions about the inter-relationships between the SEP indicators to be modelled. Singh-Manoux *et al.* provided evidence that multiple regression models where the various SEP indicators are assumed to be independent can produce different results to when inter-relationships between the models are modelled; they concluded that comparisons between different measures of SEP are meaningless if the relationships between the SEP indicators are ignored.[407]

All variables were defined and used in the same way as in earlier sections of this chapter. Initially, univariable models of the relationship between each SEP indicator and height-for-age are presented. Subsequently, bivariable models are run with the wealth index, height-for-age and each other SEP indicator in turn. This is to see whether the wealth index remains a predictor of height-for-age independently of the other SEP indicator. In these models, the relationship between the wealth index and the other SEP indicator is also modelled. Consumption expenditure, education of the household head, and community infrastructure are assumed to determine the wealth index (**Figure 10.4**). The four subjective SEP indicators (food consumption adequacy, consumption adequacy, the economic ladder question, and income sufficiency) are hypothesised to be affected by the wealth index (**Figure 10.5**). This assumption is considered plausible, since the wealth index is constructed using indicators of material living standards, which are likely to affect subjective ratings of SEP.

Finally, a model was run of the wealth index, height-for-age, and all of the socio-economic determinants of the wealth index explored in **Chapter 8**, i.e. consumption expenditure, education of the household head, and community infrastructure (**Figure 10.6**). This model allows investigation of whether the wealth index remains an important predictor of height-for-age after accounting for these socio-economic factors.

10.5.5 Results

With the exception of the economic ladder question, all SEP indicators are statistically significantly associated with height-for-age in univariable models (**Table 10.7**). The relationship is strongest for food consumption expenditure.

In bivariable models with each other SEP indicator in turn, the wealth index remains statistically significant in each case. There is little change in the coefficient estimates for the wealth index when any of the other SEP indicators are taken into account (**Table 10.8**).

In the full model with the wealth index, consumption expenditure, education, community infrastructure, and height-for-age, there are changes in both the coefficients and statistical significance of parameters (**Table 10.9**). The coefficient for the wealth index is approximately half that in uni- and bi-variable models, and the p value of the coefficient has increased substantially. Log consumption expenditure is no longer statistically significant in this model, and the statistical significance of community infrastructure is also reduced.

Figure 10.4: Path analysis models of the relationships between height-for-age, the wealth index, and other SEP indicators

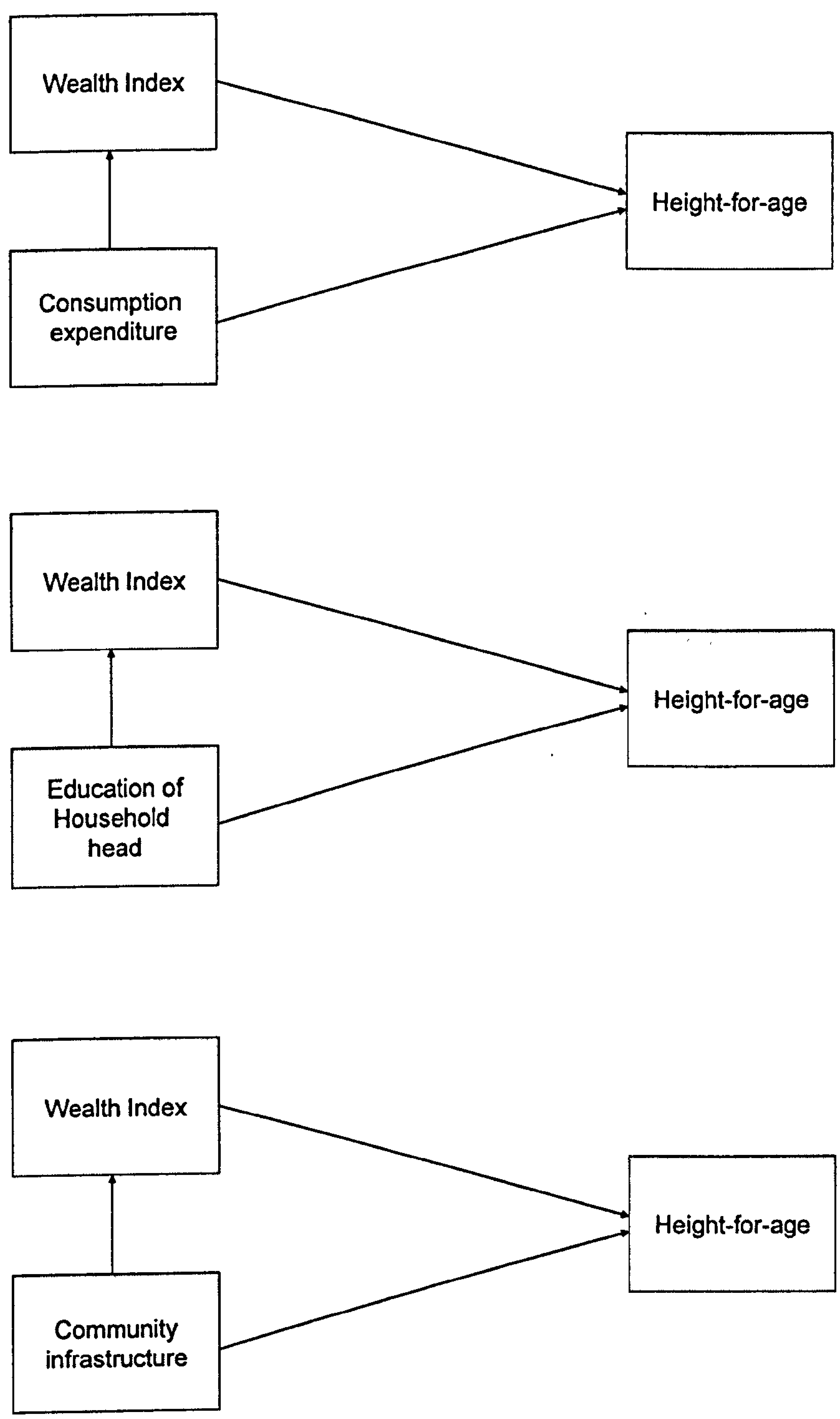
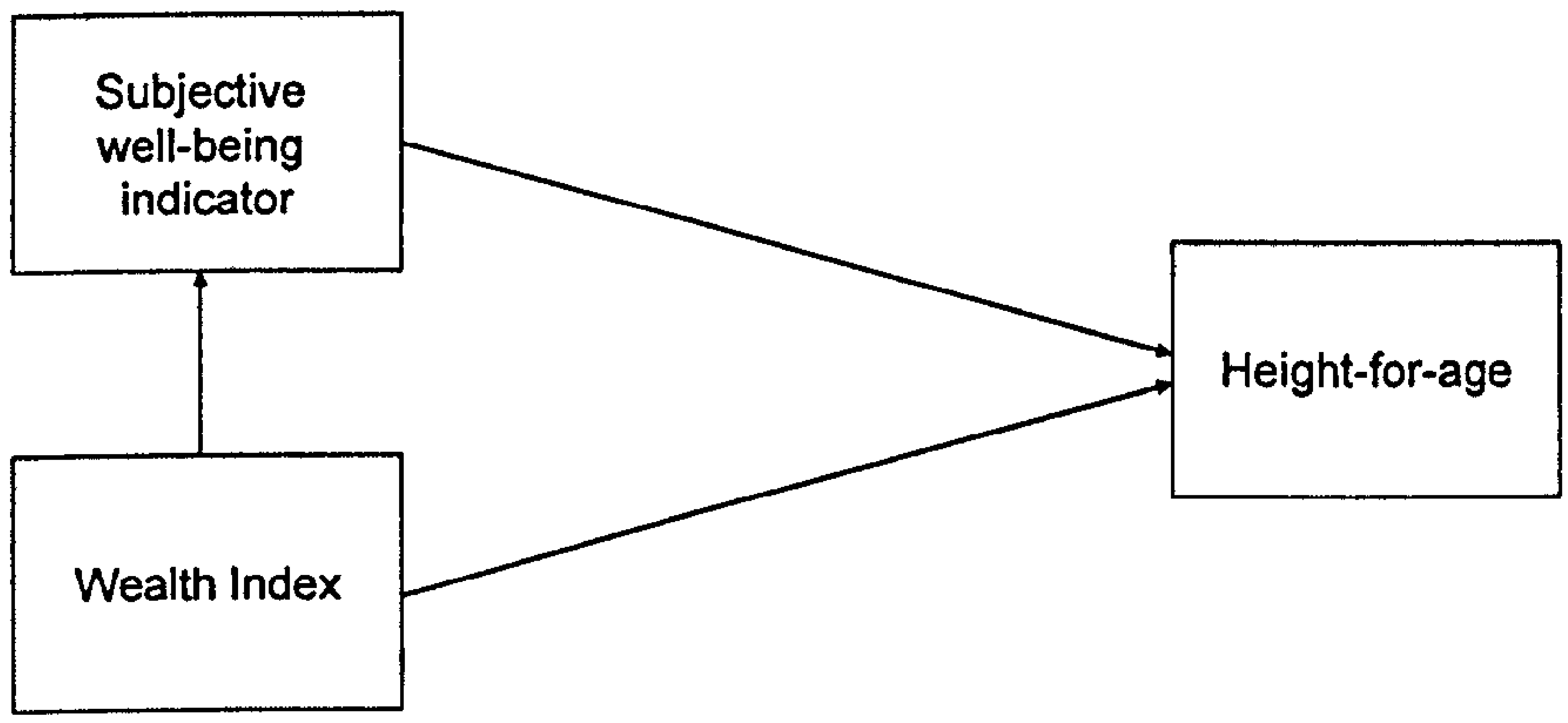


Figure 10.5: Path analysis model of the wealth index, height-for-age and subjective SEP indicators



This model was run for the four subjective SEP indicators: i) food consumption adequacy, ii) consumption adequacy, iii) economic ladder question, and iv) income sufficiency

Figure 10.6: Full path analysis model of the wealth index, determinants of the wealth index, and height-for-age

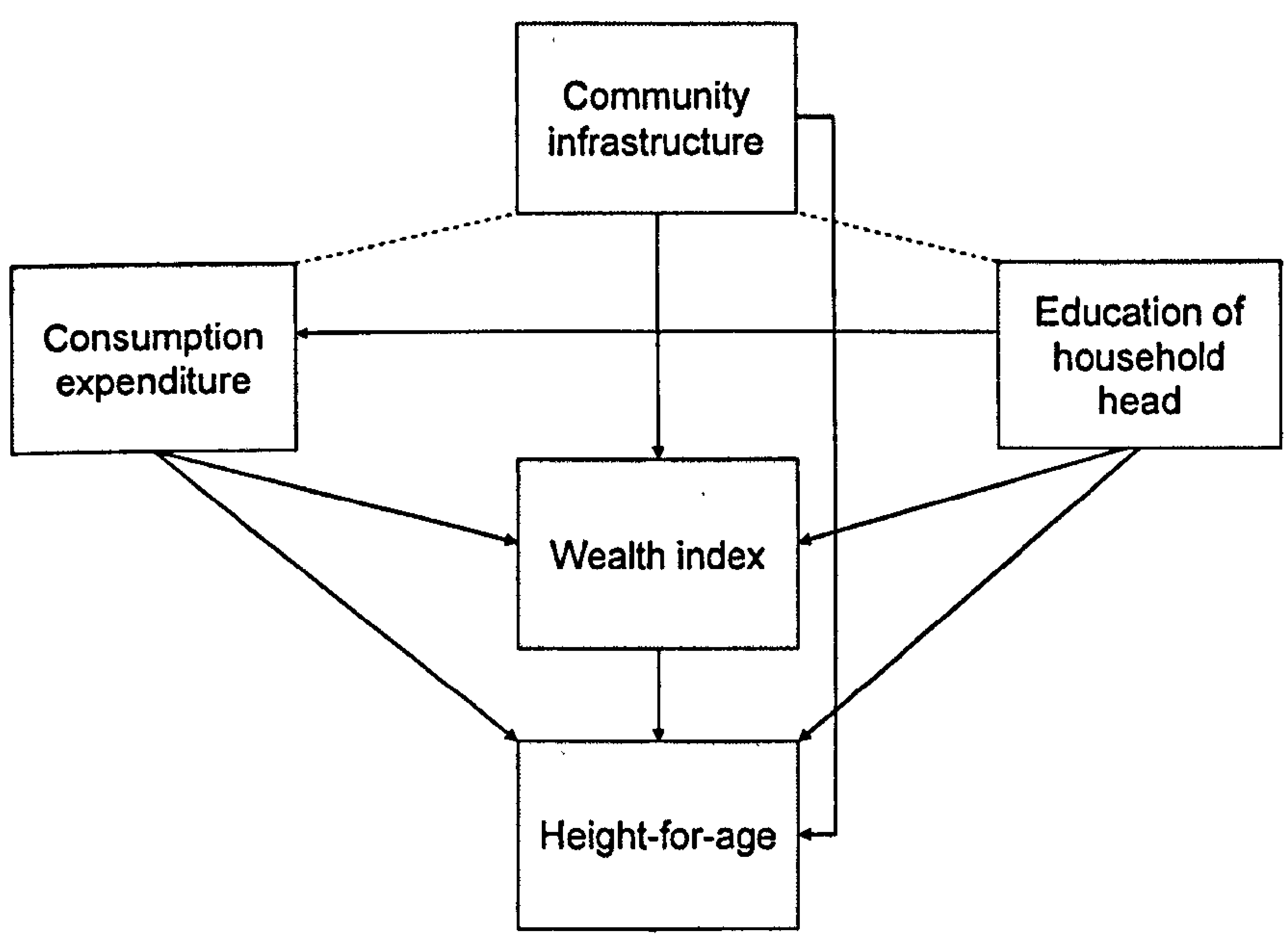


Table 10.7: Path models of the univariable relationships between each SEP indicator and height-for-age

SEP indicator	*Linear regression coefficient with height-for-age (Standard error)*	*p value*
Wealth index	0.069 (0.013)	<0.001
Log Consumption expenditure	0.163 (0.037)	<0.001
Education		
none/pre-school only	-	
primary only	-0.060 (0.037)	0.110
above primary	0.334 (0.048)	<0.001
Community infrastructure	0.081 (0.015)	<0.001
Food consumption adequacy	0.178 (0.029)	<0.001
Consumption adequacy	0.078 (0.023)	0.001
Economic ladder question	0.041 (0.024)	0.085
Income sufficiency	0.058 (0.016)	<0.001

Table 10.8: Path models of the bivariable relationships between the wealth index, each other SEP indicator and height-for-age

Model	*Linear regression coefficient with height-for-age (Standard error)*	*p value*
Wealth index	0.056 (0.014)	<0.001
Log Consumption expenditure	0.110 (0.040)	0.006
Wealth index	0.047 (0.014)	0.001
Education		
none/pre-school only	-	
primary only	-0.056 (0.037)	0.136
above primary	0.283 (0.050)	<0.001
Wealth index	0.048 (0.015)	0.001
Community infrastructure	0.055 (0.017)	0.001
Wealth index	0.058 (0.013)	<0.001
Food consumption adequacy	0.158 (0.029)	<0.001
Wealth index	0.056 (0.013)	<0.001
Consumption adequacy	0.063 (0.013)	<0.001
Wealth index	0.052 (0.014)	<0.001
Economic ladder question	0.087 (0.024)	<0.001
Wealth index	0.061 (0.013)	<0.001
Income sufficiency	0.041 (0.016)	0.011

Table 10.9: Full path analysis model of the wealth index, socio-economic determinants of the wealth index, and height-for-age

SEP indicator	*Linear regression coefficient with height-for-age (Standard error)*	*p value*
Wealth index	0.028 (0.015)	0.063
Log Consumption expenditure	0.058 (0.042)	0.160
Education		
none/pre-school only	-	
primary only	-0.062 (0.038)	0.098
above primary	0.254 (0.053)	<0.001
Community infrastructure	0.038 (0.017)	0.026

10.5.6 Discussion

The wealth index is associated with height-for-age independently of each of the other SEP indicators considered here in bivariable models. This demonstrates that, despite similarities in the magnitude of inequalities using each of the SEP indicators, the wealth index is capturing some socio-economic processes that are not captured by the other SEP indicators and that are important for height-for-age.

When a full model of the wealth index, consumption expenditure, education, and community infrastructure is run, the wealth index remains associated with height-for-age, although there is attenuation in the strength of the relationship compared with uni- and bi-variable models in terms of both size and statistical significance of the parameter.

The main implication of these findings is that the wealth index should not be used as the sole indicator of SEP in studies of determinants of health. If one is attempting to make a detailed assessment of the socio-economic determinants of a health outcome, these results suggest that the wealth index should be used in addition to other SEP indicators. This suggestion, however, ignores the fact that the socio-economic processes leading to a household's position in the wealth index hierarchy are still largely unknown, particularly in rural areas. Arguably, since the implications of an association with the wealth index are not clear, it is not useful to include it in addition to other, more easily interpretable socio-economic indicators. In particular, results may be easier to interpret with separate indicators of household- and community-level socio-economic factors rather than the wealth index, which incorporates both.

10.6 Controlling for confounding by SEP

The primary aim of observational studies is often to estimate causal associations between exposures and outcomes. This aim is hampered by the many forms of potential bias –selection bias, recall bias, reverse causality, and so on. Confounders are those factors that are associated with both the exposure and the outcome, but do not lie on the causal pathway between the two. If confounders are not considered in the design and/or analysis of a study, effect estimates will be biased. Adjustment for confounders removes this bias, but this requires both knowledge of and accurate measurement of all possible confounders. There is a substantial body of literature demonstrating that measurement error in confounders can lead to biased effect estimates.[408-411] There has also been considerable discussion surrounding the differences between observational studies in randomised controlled trials, that are generally believed to be due to unmeasured or residual confounding.[412, 413] There is also a growing body of literature emphasising that selection of confounders should be based on the assumed causal relationships between variables in a model.[414-420] Establishing causal hypotheses about relationships between variables in a model requires that the concepts being measured by each variable, potential measurement error, and pathways between different variables are understood.

It is widely accepted that a substantial proportion of exposure-outcome associations of interest to epidemiologists will be confounded by SEP. Controlling for the confounding effects of SEP is one of the most common ways a wealth index is used in epidemiological research; in one third of the studies included in the literature review in **Section 1.8**, the wealth index was the only measure of SEP used to control for socio-economic confounding.

Given the bias introduced by unmeasured or residual confounding, using the wealth index as the sole indicator to control for socio-economic confounding seems inappropriate. This is particularly true given that in **Section 10.5**, I showed that all of the other SEP indicators investigated were associated with height-for-age independently of the wealth index. Blakely *et al.* also illustrated the importance of using multiple SEP indicators, demonstrating that using only a single SEP indicator resulted in residual confounding.[421]

If causal diagrams are to be used to map out the proposed relationships between variables in a model and therefore identify confounders, the uncertainty in the socio-economic processes being captured by the wealth index means that its use, even as part of a set of socio-economic confounders, could be questioned.

A further important point in the use of a wealth index as a confounder is that the wealth index includes some important direct determinants of health such as water and sanitation. Furthermore, it is strongly determined by community infrastructure as well as by household socio-economic conditions. If any of these factors are an exposure of interest in the study, using the wealth index as a confounder could produce misleading results.

10.7 Identification of 'poor' households for program targeting

10.7.1 Background

The wealth index has been used as a tool for identification of 'poor' households for pro-poor intervention targeting and for assessing the equity of intervention coverage.[15, 102, 147, 152, 214, 422-424] The choice of targeting indicator should be based on the program's objectives, and will not be the same in every case, although consumption expenditure-based poverty lines are frequently used. The costs of a targeting process must be balanced with the ability of the process to identify those in greatest need, and therefore cheaper alternatives to consumption-based measures have been sought. Morris *et al.* demonstrated that a reduced expenditure measure could serve as an accurate proxy for consumption expenditure, but this requires an existing dataset from which predictors of expenditure can be identified.[32] Since the wealth index is a measure of relative SEP, the cut-off point for targeting has to be a certain percentage of the population, e.g. the lowest 40%. This is in contrast to consumption expenditure or income-based targeting methods, which often calculate a level of expenditure/income necessary to fulfil basic needs and use this to define a poverty line.

Skoufias *et al.* showed that a wealth index leads to severe welfare losses, since there would have been 32% programme undercoverage in rural areas, and 47% undercoverage in urban areas had a wealth index targeting method been used instead of a consumption expenditure approach.[206] They also demonstrated that there were important welfare losses when reported income was used, although this was less severe than with a wealth index. Lokshin *et al.* showed that an aggregate measure of the subjective adequacy of consumption (of food, clothing, housing, and health) was strongly predictive of reported consumption expenditure and resulted in similar poverty rates.[275] Subjective measures allow the definition of poverty to be the societal norm of acceptable standards of living. The low level of agreement between all of the SEP indicators in IHS2 and consumption expenditure (**Section 9.3**) suggest that a consumption expenditure based poverty line such as US$1-a day would result in considerable differential targeting compared with all of these SEP indicators; the extent of this differential targeting between US$1-a day and the other measures of SEP available in the IHS2 will be examined in this section. Although there has been criticism of the dollar-a-day poverty line, it is widely used by the development community as an indicator of absolute poverty in the poorest countries; the first Millennium Development Goal is to halve the 1990 dollar-a-day poverty rate by 2015.

10.7.2 Objectives

1. Quantify the targeting differential that would arise from using a wealth index rather than a US$1-a day poverty line
2. Quantify the targeting differentials that would arise from using a subjective measure of living standards rather than a US$1-a day poverty line

10.7.3 Methods

The US$1-a day poverty line was defined as per capita consumption expenditure of less than 11,051 Kwacha, as specified by the IHS2 survey documentation.[425] Dollar-a-day poverty refers to consumption expenditure of less than US$1.08 at 1993 international PPP exchange rates for the local currency; this amount is then inflated to the appropriate value for the survey year.

The targeting differential was calculated for five alternative measures: i) the wealth index, ii) the economic ladder question as described in **Section 7.4**, iii) the measure of perceived food consumption adequacy, as described in **Section 7.4**, iv) the measure of consumption adequacy (food, clothing, housing, and healthcare), as described in **Section 9.3.2**, and v) the measure of subjective income sufficiency as described in **Section 7.4**. For the wealth index, the poverty cut-off line was taken as the bottom 20% of the population, since this is the approximate percentage of the population under the US$1-a day poverty line.. For the subjective economic ladder question, the poverty line was taken as those on the bottom of the six steps. For perceived adequacy of food consumption, the poverty line was taken as 'less than adequate for household's needs'. For the measure of consumption adequacy, the poverty line is taken as the bottom 20% of the population. For subjective income sufficiency, the poor are taken as those in the bottom category, i.e. those who must borrow to meet their needs.

10.7.4 Results

The percentage of households that are dollar-a-day poor is high across the bottom four quintiles of the wealth index; in the fourth quintile almost 20% of households are dollar-a-day poor (**Table 10.10**). Using the bottom 20% of the wealth index as the poverty line, just 29% of the dollar-a-day poor are 'correctly' classified as poor by the wealth index (**Table 10.11**).

There are also high percentages of dollar-a-day poor households across all groups of the other SEP indicators, for instance over 13% of households in the top groups of the food consumption adequacy measure and the consumption adequacy measure are dollar-a-day poor, and over 20% of those who say their income is sufficient to allow saving are dollar-a-day poor (**Table 10.10**). Just 39% of dollar-a-day poor households are classified as 'poor' using the consumption adequacy measure; this percentage rises to 62% for the food consumption adequacy measure, 67% for income sufficiency, and 72% for the economic ladder question (**Table 10.11**).

Table 10.10: Distribution of the dollar-a-day poor across alternative living standards measures

	% Households dollar-a-day poor
Overall (N=11,280)	21.4
Wealth index	
Quintile 1 (lowest) (N=2326)	29.2
Quintile 2 (N=3105)	25.6
Quintile 3 (N=1467)	27.3
Quintile 4 (N=2212)	19.8
Quintile 5 (highest) (N=2133)	5.1
Economic ladder question	
Bottom step (N=5017)	29.2
Step 2 (N=4382)	17.9
Step 3 (N=1514)	7.8
Step 4 or above (N=350)	6.4
Subjective food consumption adequacy	
Less than adequate (N=6245)	27.1
Just adequate (N=4219)	14.1
More than adequate (N=350)	13.9
Subjective consumption adequacy	
Quintile 1 (lowest) (N=3142)	29.0
Quintile 2 (N=1452)	25.8
Quintile 3 (N=2698)	21.5
Quintile 4 (N=1899)	13.3
Quintile 5 (highest) (N=2076)	13.2
Income sufficiency	
Not enough, must borrow (N=5643)	27.2
Not enough, use savings (N=1430)	17.6
Just enough (N=2919)	14.6
Allows you to save a little (N=1023)	16.1
Allows you to build savings (N=256)	6.3

Table 10.11: Differential classification of poverty using alternative measures

	Dollar-a-day non-poor	Dollar-a-day poor	% poor correctly classified
Wealth index:			
Non poor (N=8917)	63.7	15.3	
Poor (N=2326)	14.9	6.1	*28.5*
Economic ladder question:			
Non poor (N=6246)	37.3	6.1	
Poor (N=5017)	41.3	15.4	*71.6*
Subjective food consumption adequacy:			
Non poor (N=6245)	46.2	8.1	
Poor (N=5029)	32.4	13.4	*62.3*
Subjective consumption adequacy:			
Non poor (N=8125)	58.2	13.1	
Poor (N=3142)	20.3	8.3	*38.8*
Income sufficiency:			
Non poor (N=5628)	41.0	7.4	
Poor (N=5643)	37.6	14.0	*66.7*

10.7.5 Discussion

In terms of its ability to identify the same households as dollar-a-day poverty, the wealth index and the measure of consumption adequacy perform equally badly, with considerably less than half of dollar-a-day poor households identified as poor. The food consumption adequacy measure, income sufficiency and the economic ladder question perform better to some extent, but even as the best performing indicator, the economic ladder question still has almost 30% under-coverage. These results indicate that none of these SEP indicators perform sufficiently well to be used as proxies for targeting of programmes or interventions if dollar-a-day poverty is accepted as the 'correct' measure on which targeting should be based.

The substantially better targeting by the economic ladder question compared with the wealth index could be argued to show that households are better placed to judge their own position within a socio-economic hierarchy than a wealth index as currently used.

The largest proportion of expenditures in settings such as this is food. This is reflected in the difference between the targeting accuracy of the food consumption adequacy measure and the consumption adequacy measure that also includes housing, clothing and healthcare.

10.8 Chapter discussion

This chapter has explored the consequences of using the wealth index as a measure of SEP, and compared the results when potential alternative SEP indicators are used. I have demonstrated that inequalities in height-for-age are similar regardless of the SEP indicator used, that the wealth index is associated with height-for-age independently of other SEP indicators, and that all of the SEP indicators considered have considerable targeting differentials compared with a poverty line based on per capita consumption expenditure. These results may to some extent alleviate concerns about the use of a wealth index to quantify health inequalities in a population, although the problem remains that the policy implications of such inequalities are unclear. Given the uncertainty over the processes being captured by the wealth index, however, its use in studies of health determinants or as a confounder is questionable. Furthermore, the results from this chapter highlight that if a wealth index is to be used in this way, it should certainly not be used as the sole SEP indicator, as is the case in many studies.

Whilst arguably more is known about the determinants of subjective measures of SEP than of the wealth index, the policy implications of these indicators are perhaps no clearer than those of the wealth index. Although the policy implications of inequalities by education are very clear – education is generally considered a exposure in itself – separate indicators of 'economic position' would ideally be used in addition to, rather than instead of, an education measure.

Despite unclear policy implications, my view is that subjective measures of SEP, particularly the ELQ, offer certain advantages over the wealth index. The determinants of the ELQ are to some extent already better understood than those of the wealth index, given that there are currently several published studies exploring them in different datasets, a growing body of relevant psychological literature on the determinants of subjective SEP, and a wider-still relevant knowledge-base on the determinants of subjective well-being. Furthermore, the determinants of subjective SEP would certainly be easier to explore through qualitative research within a given setting. The ELQ has a stronger relationship with consumption expenditure than the wealth index, although still should not be viewed as a 'proxy' of expenditure. Finally, the ELQ is more intuitive to understand, and allows respondents to determine the factors relevant to their own position within their socio-economic hierarchy rather than enforcing a set of pre-conceived notions and indicators of SEP.

As in previous chapters, the roles of occupation and employment could not be explored due to the limitations of these data in the Malawi IHS2 (**Section 9.2**). This limits the strength of conclusions that can be made, given the central role of occupation and employment in living standards.

10.9 Chapter Key Messages

1. Inequalities in stunting are broadly similar when using the wealth index or one of the alternative SEP indicators
2. Each of the SEP indicators results in considerable differential targeting compared with a US$1-a-day poverty line
3. Other SEP indicators are associated with height-for-age independently of the wealth index, resulting in concerns over the appropriateness of using the wealth index as the sole indicator of SEP when used as a potential determinant of health or confounder

10.10 Next steps

This chapter concludes my analyses of the consequences of using a wealth index. In the next and final chapter, I summarise the findings of this thesis, discuss the strengths and limitations, and draw some overall conclusions and recommendations.

Part VI: Overview

11. Discussion and conclusions

In this concluding chapter, I draw together and discuss the thesis as a whole. Initially, I provide an overview of the rationale for the research, and the main findings for each of my objectives. Subsequently, I discuss the value of this work, outlining its strengths. I then go on to discuss the limitations and methodological considerations of the thesis and how I have attempted to address them where possible. The results in each chapter have been discussed individually, and I will not repeat this here. Rather, I discuss the results of the thesis as a whole, how it links in to the wider literature, and some of the challenges facing researchers wishing to use a measure of socio-economic position. I draw some overall conclusions, and provide recommendations for further research.

11.1 Overview of thesis

11.1.1 Thesis rationale

The wealth index is a widely-used measure of socio-economic position in low- and middle-income countries. Although it was originally intended for use in existing datasets where no alternative economic indicators are available, the wealth index approach is now also popular for primary data collection. A literature review of papers citing Filmer & Pritchett's seminal paper showed that the approach is used in many different low- and middle-income settings, and in a variety of types of study. It is used for quantifying inequalities, exploring the determinants of health and other outcomes, and for controlling for socio-economic confounding. A substantial proportion of studies in the review using the wealth index for the exploration of determinants or the control of confounding used the wealth index as the sole indicator of SEP. This review also demonstrated that the methods of wealth index construction used by those constructing wealth indices from DHS data – the use of PCA for weighting the indicators in a wealth index, the approach of generating a single index for mixed urban and rural areas, and the number and types of indicators included in the wealth index – have been adopted by the vast majority of those using the wealth index.

Despite its popularity, methodological research on the wealth index is limited, and important questions remain unanswered. In particular, the socio-economic processes giving rise to a wealth index hierarchy are unclear.

This thesis has attempted to summarise the main concerns surrounding the construction and use of a wealth index, explore these issues, and make some recommendations for those deciding whether and how to use a wealth index.

11.1.2 Summary of main findings

In this section, I present the main findings of this thesis for each of the four main research questions I have addressed (**Table 11.1**). For each research question, I describe the main findings for each of the thesis objectives listed in **Section 1.9.4**. Following a discussion of the strengths and weaknesses of the analyses in this thesis, these results are discussed and brought together to form an overall picture.

Table 11.1: Main objectives and findings of thesis

Research Question 1: What is the relationship between the wealth index and consumption expenditure?

Chapter	*Objective*	
3	*1*	*To conduct a systematic review of the literature evaluating the ability of a wealth index to proxy consumption expenditure* • A systematic review of the literature demonstrated that there is variation in the ability of a wealth index to proxy consumption expenditure; the majority of datasets demonstrated weak agreement but a non-trivial number of examples of moderate and weak agreement were identified • The following factors were associated with increased agreement between the wealth index and consumption expenditure: i) urban compared with rural areas, ii) middle-income compared with low-income settings, iii) increased number and range of indicator in the wealth index, and iv) total consumption expenditure rather than per adult or per capita
4	*2*	*To quantify the agreement between the wealth index and consumption expenditure, and explore the effect of the equivalence scale used to adjust expenditure for household size and composition on this agreement.* • In the Malawi IHS2 data, agreement between the wealth index and consumption expenditure is weak, and is not affected by the equivalence scale used for consumption expenditure
4	*3*	*To explore whether the agreement between the wealth index and consumption expenditure is affected by the items used to construct the expenditure aggregate* • In the Malawi IHS2, agreement is not stronger between the wealth index and a restricted measure of consumption expenditure using only consumption items more similar to the types of indicators in the wealth index

Research Question 2: Are the methods used to construct wealth indices with DHS data the most appropriate?

Chapter	*Objective*	
5	*4*	*To explore and evaluate issues in the use of principal components analysis for weighting the indicators in a wealth index* • The first principal component from a PCA only explains a low proportion of total variance in the wealth index indicators, but higher order principal components do not result in indicator weights that can be readily interpreted with respect to SEP • The use of dummy variables for categorical variables in PCA is inappropriate; ordinal variables should be treated as continuous terms. If nominal variables must be included, multiple correspondence analysis should be used • Simpler weighting methods such as simple sum and inverse proportion are not recommended
6	*5*	*To explore approaches to wealth index construction for separate areas (urban, peri-urban, and rural) and compare these area-specific wealth indices with indices generated for the whole population* • There are strong differences in wealth index characteristics between urban, peri-urban, and rural areas, but the patterns are setting-specific • Agreement with consumption expenditure is higher in urban areas compared with rural areas in the Malawi IHS2 data, and urban households tend to be ranked higher by the wealth index than by consumption expenditure • Removing key urban-biased indicators from the wealth index had little impact on the urban/peri-urban/rural patterns in wealth index characteristics in Malawi, and constructing separate wealth indices for urban, peri-urban, and rural areas did not result in less clumping or truncation of wealth index distribution, and in some cases worsened the problem

Chapter	*Objective*	
7	*6*	*To evaluate the effects of including and excluding different sets of indicators in the wealth index* • Increasing the number of indicators in a wealth index results in a less clumped distribution in the Malawi IHS2 data • Including productive assets, additional consumer durables and service indicators, human capital and demographic indicators, or subjective SEP indicators reduced the observed gap in wealth index scores between urban and rural households in Malawi • Broadening the types of indicator used to construct a wealth index had little effect on its agreement with consumption expenditure in Malawi

Research Question 3: What socio-economic processes contribute to the wealth index hierarchy?

Chapter	*Objective*	
8	*7*	*To explore the determinants of wealth index scores, and hence to attempt to improve interpretation of the results of analyses using the wealth index* • Wealth index scores are determined by both household- and community-level factors • The strength of the relationships between the wealth index and other socio-economic factors differs between areas; all factors are stronger predictors of wealth index scores in urban areas • Key socio-economic factors explain only a very low proportion of variance in wealth index scores, particularly in rural areas

Research Question 4: What are the alternatives to the wealth index?

Chapter	*Objective*	
9	*8*	*To explore potential alternative SEP indicators* • Agreement of the wealth index with other SEP indicators is generally low, such that using alternative SEP measures results in different conclusions about the socio-economic hierarchy • None of the alternative SEP indicators presented here has very strong agreement with consumption expenditure, although the ELQ and food consumption adequacy had stronger agreement than the wealth index and other SEP indicators considered here • Subjective SEP indicators that can be captured with a single question appear to have similar relationships to education and consumption expenditure to the wealth index, but are not strongly influenced by community infrastructure in the way that the wealth index is • The proportion of variance explained by the key SEP indicators education and consumption expenditure is lower for subjective SEP indicators than for the wealth index
10	*9*	*To explore the consequences of using the wealth index instead of potential alternative SEP indicators* • Inequalities in stunting are broadly similar when using the wealth index or one of the alternative SEP indicators • Each of the SEP indicators results in considerable differential targeting compared with a US$1-a-day poverty line • Other SEP indicators are associated with height-for-age independently of the wealth index, resulting in concerns over the appropriateness of using the wealth index as the sole indicator of SEP when used as a potential determinant of health or confounder

11.2 Strengths and value of this work

Value of the research

The wealth index is a novel approach to socio-economic position measurement, and was originally proposed for the analysis of existing datasets where no other economic measures are available. Despite this, it has become increasingly popular for primary data collection. Furthermore, the indicators and methods used to construct the wealth indices within the DHS have become 'standard' practice, used extensively by the wider research community. There is therefore need for a thorough evaluation of the wealth index approach, its strengths, limitations, and the consequences of constructing and using it in different ways. There has been only a limited amount of methodological research on the wealth index approach, particularly with a view to evaluating its use in primary data collection. This thesis has attempted to fill in some of the gaps in the knowledge and provide some guidance to those deciding whether and how to use the wealth index.

Thorough literature reviews

Evaluating the literature on papers using the wealth index has demonstrated the widespread use of the approach, and highlighted that the methods and indicators used by the DHS have been adopted by the wider research community as 'standard'. This literature review allowed the research questions and objectives of this thesis to be developed in the light of existing methodological research on the wealth index, and with the aim of answering questions pertinent to the ways in which wealth indices are being used.

The evidence on the ability of a wealth index to act as a proxy for consumption expenditure had not previously been consolidated. Getting an overall picture of the body of evidence on this topic is important since some proponents of the wealth index have put the wealth index forward as a proxy for consumption expenditure, meaning that researchers and users of research may inappropriately be interpreting results based on the wealth index as equivalent to consumption expenditure.

Breadth of issues considered

I have evaluated a wide range of issues to do with wealth indices, which has allowed this thesis to build up a holistic picture of evidence and recommendations about the construction and use of wealth indices.

The socio-economic processes giving rise to the wealth index hierarchy

Aside from studies looking at the relationship between the wealth index and consumption expenditure, the nature of the socio-economic processes contributing to a wealth index hierarchy have hitherto received little attention in the literature. I have demonstrated that household socio-economic factors and community infrastructure both affect the wealth index hierarchy, but that key socio-economic indicators explain a very low proportion of the variance in wealth index scores in rural areas of Malawi. This sheds some light on the social stratification processes giving rise to wealth index scores, but also highlights that household socio-economic position may not be the main reasons for differences in wealth index scores between households in rural areas.

Quality of data and statistical methods

The data used in this thesis come from high-quality, nationally-representative datasets with large sample sizes. Statistical methods have been selected that allow the investigation of relationships as fully as possible – for example multiple imputation was used to explore the impact of missing height data, and path analysis allowed for the relationships between the wealth index and its socio-economic determinants to be mapped out in a more complex way than sequential regressions would have permitted. Analyses have taken account of the sampling design of the surveys. Using an LSMS dataset has facilitated the exploration of issues that cannot be considered in a DHS or similar dataset – e.g. agreement with consumption expenditure, the use of a wider range of indicators, and issues surrounding the use of alternative SEP indicators such as subjective measures of SEP. It also facilitated the creation of an indicator of community infrastructure, since both household- and community-level data are available for the same population.

11.3 Limitations of this work

Generalisability

The analyses in this thesis are based largely on data from Malawi, with limited re-analysis using data from Brazil. Given the differences between countries in socio-economic conditions, and in the availability, affordability, and desirability of the items used to construct the wealth index, results cannot readily be generalised to other settings. Where analyses were conducted in both the Malawi IHS2 and the Brazil DHS, striking differences were seen between the two countries. Judging from the distributions of the wealth indices in each dataset, the wealth index struggles to differentiate between the rural poor in Malawi and the urban rich in Brazil. This is unsurprising given that the majority of households in rural Malawi have relatively few of the 'standard' wealth index items, and the majority of urban households in Brazil possess most or all of the items. This difference, whilst being a limitation in terms of the generalisability of the results from analyses in this thesis, is also important in itself as a warning to those conducting primary research against reliance on the items used by the DHS.

Although no analysis on a single dataset can be assumed to be representative of all other situations, the impact of using only one or two datasets is likely to differ for the different parts of this thesis. Some of the findings related to statistical issues, e.g. issues relating to PCA, may be more likely to be similar across different settings. Other issues, such as the relative importance of different socio-economic processes to the wealth index hierarchy are likely to be considerably more affected by setting and therefore less generalisable.

In terms of the work on the socio-economic processes contributing to a wealth index hierarchy, I would hypothesise that many of the patterns seen would be similar in countries with similar economic conditions, but vary substantially between countries with different levels of economic development. A related issue is that of time; the 'meaning' of the items used to construct a wealth index can be expected to differ not just between places, but over time. As consumer durables and public services become more available and affordable, they are less likely to be confined to those at the top of the socio-economic spectrum. Again, this is most likely to affect my findings about the socio-economic processes contributing to the wealth index hierarchy, the importance of which is unlikely to remain static over time.

A further issue of generalisability is that where the wealth index has been compared with potential alternative SEP measures for different purposes (**Chapter 10**), the analysis is restricted to using child stunting as a measure of health. The results may not be generalisable to other health outcomes. The importance of different SEP indicators may vary for different health outcomes, and therefore the magnitude of inequalities, and whether alternative SEP indicators are associated with a health outcome independently of each other may vary. For instance the relative importance of maternal education compared with other SEP measures may vary across the lifecourse; its influence and the pathways through which it can affect health vary between health outcomes and change over time as a mother's role in her child's life changes. The relative importance of different SEP indicators will also vary between different types of health outcome; stunting is a chronic condition whose socio-economic determinants will differ from acute diseases.

Measurement error and bias

Measurement error can be a source of bias in all epidemiological studies. Some have argued that high reliability and low potential for measurement error is one important advantage of the wealth index over other SEP indicators; the extent to which this claim is justified is largely unknown, although one study has demonstrated at best modest inter- and intra-observer reliability.[245] Although the wealth index generally relies on indicators that could be observed by the interviewer, most staff will record responses based on verbal information provided by the informant and would not attempt to validate responses. There could, however, be conflict between what the interviewees report to the researcher, and what the researcher believes to be the case – this conflict may be resolved in different ways by different researchers, and questionnaires and interviewer training should make it clear whether the recorded response should be based primarily on observation or on reported answers.

The measurement of consumption expenditure is certainly fraught with difficulties, and recall bias is likely to be an important issue. Respondents are highly unlikely to have an accurate recall of the precise quantities of each item, nor of the exact prices paid for items. Recall of quantities of home-produced goods is also questionable. The imputations required for placing a value on home-produced goods are also complex and subject to bias.[30] Imputations for rental value of housing are also highly questionable given the limited housing market in many low- and middle-income settings.[32] The use of consumption expenditure as a benchmark against which to judge the wealth index could be questioned. Although many economists view consumption expenditure as the 'gold standard' measure of economic position in low- and middle-income countries, it does suffer from considerable measurement issues and is not the only aspect of economic position that determines well-being in these settings. It would be difficult to judge alternative ways of constructing the wealth index by the features of the wealth index alone. Despite the limitations of consumption expenditure, its use as a standard against which to judge different constructions of the wealth index was considered justifiable given the dominance of consumption expenditure in economic studies in low- and middle-income settings, and the claims by proponents that the wealth index is a suitable proxy for consumption expenditure. Furthermore, the systematic review demonstrated variation in the ability of a wealth index to proxy consumption expenditure. This indicates that it is possible for there to be high agreement between the two measures; if features of wealth index construction that could improve the agreement could be identified, this would strengthen the role of the wealth index in epidemiology and other research disciplines.

Subjective measures of SEP require the assumption that all respondents interpret the questions in a similar way and base their answers on similar factors. It may be the case that individuals from rural areas rate their SEP as higher than individuals of equivalent SEP (as judged by an objective indicator) from urban areas, since those from rural areas may be less exposed to and aware of the greater wealth in urban areas; i.e. their frame of reference is different. This may particularly have affected the generalisability of the analyses in **Chapters 9 & 10**, since the determinants of subjective SEP, and its relationships with other SEP indicators and with health are likely to differ markedly across settings, times, and health outcomes.

Data from the community questionnaire are subject to bias since they are collected from the opinions of a small group of community-members, who may not represent the overall views of the community. The use of census enumeration areas as 'communities' is also problematic, since they represent administrative boundaries and may not meaningfully reflect what individuals and households consider to be their community. To address this in the community questionnaire, a single 'village' or 'urban-area' was assumed to be representative of the whole census enumeration area. These villages or urban area were attempted to be defined by the community's own view of what constitutes the community. The extent to which these villages and urban areas are representative of the whole EA is largely unknown. There are, however, likely to be a number of instances where measurement error has been introduced as a result of the community questionnaire methodology. For instance, generation of the community infrastructure variable used community questionnaire data on whether certain services or facilities were present or absent from the community; whether the situation is the same for households in different parts of the same EA is uncertain. I attempted to validate the community data as far as possible by comparing aggregate measures from the household survey with indicators from the community questionnaire; the match was generally good, but such validation was only possible for a few selected indicators. Bias in the community questionnaire will primarily have affected the indicator of community infrastructure used in analyses of the determinants of the wealth index and alternative SEP indicators.

Anthropometry data are subject to bias due to errors in conducting measurements and recording both age and height data. Whilst training procedures for the researchers carrying out the IHS2 data collection appear to have been thorough, inter- and intra-observer data is not available to assess the reliability of measurements. The difficulties with age data in the Malawi IHS2 data, and the methods I used to attempt to get the best possible estimate of age were discussed in detail in **Section 10.4.3.2**. For both height and age data, I attempted to minimise biases by investigating outliers, and by using methods to impute missing data.

Causality cannot be established

Although I have attempted to shed some light on the socio-economic processes contributing to wealth index scores, this picture remains uncertain, particularly in rural areas. Within the constraints of this thesis, a full analysis of a wide range of factors potentially affecting wealth index scores was not possible, but would make a further useful contribution to the understanding of the wealth index. Furthermore, the associations between the wealth index and its socio-economic 'determinants' cannot be assumed to be causal. The data are cross-sectional, and proposed directionalities between SEP indicators are hypothetical and based on considerable assumptions. Additionally, the roles of other factors not included in these models cannot be judged; i.e. the relationships may be confounded by other factors.

11.4 The wealth index and its role in epidemiology

In this section, I aim to add my results to the existing literature, and bring together the results of each chapter and the wider literature. I attempt to draw some overall conclusions and recommendations about the wealth index as a measure of SEP.

11.4.1 How should a wealth index be constructed?

Once the decision has been made that a wealth index is to be used as a measure of SEP, the researcher faces questions about the best way of constructing the wealth index. The literature review in **Section 1.8** demonstrated that the methods used by those constructing wealth indices for the DHS have been adopted by many of those using the approach for primary data collection, but the results of this thesis suggest that in some respects this may not be appropriate. The results also imply that some modifications are advisable to the way wealth indices are constructed within the constraints of pre-existing datasets.

The issues relating to how to weight the indicators in a wealth index are relevant to all users of wealth indices, whether for existing data or primary data collection. There has been discussion in the literature about concerns relating to the use of PCA for wealth index construction,[271, 293] but I have demonstrated that PCA remains the most widely used method for weighting the indicators in a wealth index (**Chapter 1**). I have also demonstrated that all methods of incorporating nominal variables into PCA are flawed (**Chapter 5**). Since alternative weighting methods also have drawbacks, I would advocate either i) using ordinal variables as continuous score variables in PCA, or ii) using multiple correspondence analysis if categorical variables cannot be assigned an ordinal structure. Assuming the results from the Malawi IHS2 data can be generalised, the existence of methods appropriate for discrete data and the differential classification observed means that the use of PCA with dummy variables cannot be justified.

I have demonstrated that there is little benefit in constructing separate wealth indices for urban, peri-urban, and rural areas (**Chapter 6**). Agreement with consumption expenditure is not improved and clumping and truncation of the wealth index distribution may be worsened. There is strong evidence, however, that the characteristics of a wealth index, and its ability to differentiate between households, differs substantially between urban and rural areas (**Chapter 6**). These patterns seem to be setting-specific. If the results from Malawi and Brazil are assumed to be representative of the areas they are from, it appears that in settings such as sub-Saharan Africa, a wealth index struggles to differentiate between rural households, a large majority of which do not possess any of the wealth index indicators. In contrast, in higher-income settings such as Brazil, many urban households possess all of the indicators, meaning that the wealth index is unable to differentiate adequately between urban households.

A further issue related to wealth index construction is the choice of indicators. Whilst those using existing datasets are restricted by data availability, designing a new study allows the selection of any indicators deemed appropriate. My analyses have shown that the choice of indicators has little impact on the agreement of the wealth index with consumption expenditure, but can substantially alter the urban-rural patterns of wealth index characteristics (**Chapter 7**). Including a greater number and broader range of indicators in a wealth index can improve the ability of a wealth index to differentiate between rural households. Indicators should be selected in a setting-specific manner, and should be hypothesised to be good indicators of

SEP. Increasing the number of variables in a wealth index is likely to smooth the distribution of the wealth index, i.e. reduce clumping and truncation, regardless of the types of indicator used as long as those indicators result in an increased dispersion of household scores. This will not, however, represent a useful improvement to the wealth index's properties unless the additional variables are believed to be good indicators of SEP.

Where recent LSMS-type data are available, indicators predictive of consumption expenditure can be identified, which can to some extent increase the agreement of the wealth index with consumption expenditure. Alternatively, where resources permit, formative research can be carried out to select a range of indicators identified by community members as being indicative of a household's SEP.

11.4.2 Uncertainty over what the wealth index measures

The key issue surrounding the wealth index is the lack of clarity in its conceptual meaning. The evidence from both the systematic review of the literature and the analyses in this thesis demonstrates that the wealth index cannot automatically be assumed to be a good proxy for consumption expenditure (**Chapters 3 & 4**). Although there was variation in the level of agreement between the wealth index and consumption expenditure amongst the studies included in the systematic review, the majority of studies demonstrated weak agreement. This holds true for many countries and many ways of constructing the wealth index. It also applies to a variety of alternative equivalence scales for consumption expenditure, such that the wealth index does not appear to be measuring total household, per adult, or per capita consumption expenditure (**Chapter 4**).

Consumption expenditure is intended to measure permanent income. The concept of permanent income refers to planned and anticipated income, i.e. the income expected to be received in both the short- and longer-term. Economic theory states that decisions about consumption (and therefore consumption expenditure) are based on permanent income, such that households 'smooth' their consumption and do not overly reduce or increase it in response to what are perceived to be short-term income fluctuations. Consumption expenditure, however, is a proxy for permanent income rather than a direct measure of it. There are substantial measurement issues associated with consumption expenditure; it relies on accurate recall of expenditures on a very wide range of items that may not have been purchased by the interviewee, it necessitates complex calculations for imputing the rental value of housing, the value of durable goods, and the value of home-produced goods, and it requires elaborate adjustments for prices of goods to allow for price differences across regions. It is therefore likely that consumption expenditure itself is not a perfect proxy for permanent income. The generally low agreement between the wealth index and consumption expenditure implies that the two measures are not capturing the same economic processes. It is possible that the wealth index is not a good measure of permanent income, or that the wealth index and consumption expenditure are simply measuring different aspects of permanent income; the wealth index may represent a longer-term facet of permanent income, since the indicators used to create the index all represent decisions and economic circumstances over a longer timeframe than many of the items included in a consumption expenditure measure. Bollen *et al.* consider consumption expenditure, ownership of consumer durables and housing quality to be distinct effects of permanent income, whereas they view education and occupation as determinants of permanent income.[94] This notion would be difficult to test empirically given that permanent income itself is inherently unobservable.

The analyses in this thesis have shown that wealth index scores are determined by both household- and community-level factors (**Chapter 8**). This mixing of effects complicates the interpretation and policy implications of findings – should household- or community-level social policy interventions be advocated, and what would be the estimated impact on inequalities of each type of policy approach? Given the independent importance of community infrastructure over and above the effects of household SEP for health and for development targets such as the Millennium Development Goals[426], separating the effects of household- and community-level effects is crucial for intervention design, evaluation, and progress monitoring. Although all measures of SEP included in the Malawi IHS2 data are correlated with community infrastructure, the relationship is strongest for the wealth index. The wealth index appears to be driven more by community infrastructure than potential alternative SEP indicators.

Additionally, I have shown that a set of key socio-economic indicators explained only a modest proportion of the total variance in wealth index scores, and that this proportion is far lower in rural areas than in urban areas. Thus the socio-economic, or other, processes giving rise to the wealth index hierarchy remain uncertain, particularly in rural areas. The wealth index has limited agreement with the objective and subjective SEP measures in the Malawian dataset used in this thesis (**Chapter 10**), and has been shown in a study in South Africa to have poor agreement with participatory wealth ranking.[322] If these results are generalisable, it therefore appears to be strongly related to neither established markers of objective SEP, nor to SEP as perceived by community members.

Wealth indices are clearly measuring something that is an important determinant of a wide variety of health outcomes across many settings, as demonstrated by the overview report detailing inequalities in a wide range of health outcomes across 56 DHS studies.[58] I showed that the wealth index is associated with height-for-age independently of a wide range of other SEP indicators, including both objective and subjective measures (**Chapter 10**). The wider literature also indicates that the wealth index is measuring something that is important for health independently of other aspects of SEP. For example, a study using nine DHS surveys and 12 LSMS datasets from Latin America demonstrated that there were both independent effects of, and interactions between, wealth indices and maternal and paternal education.[158] Simply being predictive of health, however, does not make the wealth index a useful exposure in epidemiological studies.

Without a clear understanding of the causal mechanisms linking exposures to health outcomes, and the implicated policy responses, social epidemiological studies are of limited value.[23] Nonetheless, the important role the wealth index has had on putting health inequalities on the map of global health should not be dismissed. The DHS represent an unparalleled source of high-quality, nationally-representative health, nutrition, and population data in low- and middle-income countries. Developing the wealth index methodology has allowed the quantification and comparison of socio-economic inequalities in health on a larger scale than has ever before been possible in low- and middle-income settings. Furthermore, the approach has been adopted by the UNICEF MICS, which have similar questionnaires to the DHS but limited geographical overlap, further increasing the number of low- and middle-income countries for which health inequalities estimates are now available. The advocacy surrounding the work by the DHS and MICS has surely increased the prominence of health inequalities research in general. Furthermore, the wealth index is now being used to assess equity aspects of the Millennium Development Goals – important international development targets that until very recently placed no emphasis on equity issues. I would certainly argue that the wealth index approach has an important place in studies such as the DHS where no alternatives exist, and that it has played a vital role in advocacy for health inequalities. My main concern lies with the adoption of the wealth index approach by the wider research community, and the emergence of the indicators and techniques used by the DHS as a 'standard' methodology for primary data collection.

11.4.3 Ideological implications of the wealth index

Social epidemiological studies are defined by the fact that they focus specifically on social and economic influences on health. In order to design and analyse a social epidemiological study, a view of the world and how it affects health is necessary, i.e. the research must be based on social theory. All social epidemiological research has aspects of social theory, although all too often the researcher's assumptions are implicit or unclear rather than explicit and carefully thought through. Measures of SEP reflect not just discipline, traditions, and current fashions, but also ideology.

It is difficult to see exactly how the wealth index fits in with any of the sociological or economic theories of social stratification. It is certainly not capturing a Marxian view, since it captures no information on relationship to the means of production. It could to some extent be considered to reflect aspects of Weber's class domain, since economic resources will affect a household's probability of having certain dwelling characteristics, owning consumer durables, or having access to the service indicators in the wealth index. Little information can be obtained about prestige or power from a wealth index score, although there may be a certain degree of prestige associated with some wealth index indicators.

With the methodology used by the DHS and most other researchers to construct a wealth index, a similar set of indicators of material living conditions are used to construct an index, and this index is assumed to represent 'SEP'. If no formative research is conducted in a given setting to explore the meaning of these items to the local population, or better to identify prior to data collection a set of items that are viewed as being associated with high SEP, this approach to SEP measurement is rather positivist. It stands in stark contrast to participatory approaches and subjective measures, which allow the people themselves to rate their social and economic standing as they see it. There is perhaps a tendency for some researchers to view constructivist measures such as PWR and subjective measures as softer or weaker measures, providing less strong evidence than objective indicators. Arguably, however, the difference is not in the strength of evidence, but in the processes being captured and the degree to which they are measuring concepts of relevance to the local population. McGee and Brock discuss the role ideology and organisational aims play in choices of poverty measurement, using the examples of the World Bank Development Report 2000 and Oxfam's Poverty Report. Whilst the World Bank's World Development Report did draw on some qualitative and participatory work, this was far from an integral part of the report, and was not really considered 'data', rather it was used as "illustrations and flousishes". Oxfam's Poverty Report, on the other hand, takes a holistic and structural view of poverty, linking poverty to conflict, gender discrimination, and so on. Here, qualitative data forms an integral part of the report. The authors discuss how these different approaches reflect the ideology and aims of the organisations carrying out and presenting the research.[427]

A further ideological issue related to the wealth index is that of the indicators commonly used to construct wealth indices. When used in social epidemiological research, an SEP indicator should have both an underlying theory about the aspects of social stratification it represents, and also hypothesised pathways to health. Whilst I have discussed the lack of clarity of the wealth index as a whole in both of these issues, it is possible to consider the variables used to construct the wealth index. A good example is that of the car, which is not only used in the wealth index, but has been used across many studies and settings as an indicator of high SEP.[428] In terms of social stratification, the car is an expensive item to acquire, run, and maintain. Its relationship to health, however, is more complex. In low- and middle-income settings, the car is assumed to be associated with good health through increased access to healthcare due to an improved ability to get to health centres both for routine and emergency care.[56] This notion, however, rests on considerable assumptions, e.g. that road conditions are more amenable to cars than to pedestrians or other modes of transport and are free from congestion, and that health care is primarily provided in centres at a considerable distance from people's homes. When conducting social epidemiological research that explores socio-economic inequalities in health, the implication is typically that increased access to markers of socio-economic distinction would reduce health inequalities. Increasing levels of car ownership are not, however, necessarily good for public health. There is already a phenomenal burden of road traffic incident-related injuries in low- and middle-income countries[429], which remains a largely neglected epidemic. Increased car ownership is also associated with decreased active transport and therefore physical activity, which is linked to nutrition and epidemiological transitions; the burden of obesity, cardio-vascular diseases, diabetes, and so on increases as people consume more calories and expend less energy through physical activity.[430-433] As ownership increases so air and noise pollution also increase, and the scale of the problem of car ownership is moving from a local one to a global one (climate change). Incorporating car ownership into a measure of SEP, and thereby implicitly using it as an indicator of positive socio-economic processes therefore risks placing value on commodities and processes that the public health community is now striving to alter in high-income settings.

Although such strong arguments may not be so clear for the other wealth index indicators, all of the items commonly used to create a wealth index are associated with urbanisation, participation in a cash-based economy, and globalisation.[243] Using a wealth index therefore has the embedded assumption that urbanisation and economic growth are positive forces to be encouraged. Whilst unarguably a significant proportion of the world's population are living in extreme poverty and the global community should be acting to rectify this situation, the form that such economic development should take could be debated. The WHO Commission for the Social Determinants of Health calls for greater consideration of equity issues in economic development.[12] Researchers should be aware of the social theory underlying the socio-economic indicators they make use of; utilising a measure based largely on ownership of consumer durables is making a very different statement about views of the driving forces behind socio-economic inequalities in health compared with using participatory or subjective SEP measures.

11.4.4 If and when to use a wealth index

The choice of SEP indicator should be based on the specifics of the study; the setting, the health outcome and proposed causal relationship to health and covariates, the proposed analyses, and the available resources will all be important factors. When using existing datasets such as the DHS the choice of SEP indicator is clearly limited by the available variables. Gwatkin *et al.* acknowledge that the wealth index method was borne of convenience and developed with the aim of making the best of the available data.[58] For primary data collection, a wide range of possibilities are open to the researcher for SEP measurement.

Many economists would argue that consumption expenditure is the preferable measure of economic position. There is a general view that the collection of consumption expenditure data within the context of an epidemiological study is unfeasible. Given that a full consumption expenditure data generally requires about an hour of interview time, this may be a reasonable view. There is evidence, however, that a restricted list of consumption items can produce reasonable agreement with a full expenditure measure.[32] The method applied by Morris *et al.* requires an existing dataset with a full consumption expenditure measure for identifying the restricted list. This will be possible in many low- and middle-income countries, where LSMS datasets are available or where national statistics offices have conducted similar surveys with expenditure data. Obtaining and analysing these data is often, however, a complex and time-consuming undertaking, as was the case for the Malawi IHS2 data used in this thesis. A further possibility when recent full consumption expenditure data are available is to use the consumption correlates approach to identify those consumer durables and housing characteristics that are predictive of consumption expenditure, and construct a wealth index from these indicators.[295] It is difficult to suggest which of these two options is preferable when LSMS-type surveys are available. Morris demonstrated a strong correlation (r=0.72) between the reduced list and the full consumption expenditure aggregate in his study in rural Côte d'Ivoire, but to my knowledge this is the only example of this type of analysis. The consumption correlates approach has been applied in a variety of settings. It was shown in the systematic review that the method tends to produce a wealth index with a stronger association with consumption expenditure than when indicators are selected by other means, but the three studies adopting this approach each demonstrated moderate rather than strong associations with consumption expenditure. My suggestion, therefore, would be to explore the LSMS-type data for the particular setting, and see what level of agreement with the full consumption expenditure aggregate can be achieved with each approach, and choose the most suitable for the particular setting. The objectives of the study should also play an important role in deciding whether collecting full consumption expenditure data is feasible. In those epidemiological studies where SEP is of interest as a confounder, it is a reasonable assumption that resources will not permit the collection of full consumption expenditure data. However, if the primary focus of a study is to quantify or understand socio-economic differentials in health, collection of full consumption expenditure data may well be justified.

Most would agree that education does not capture a purely economic concept. The benefits of education are far greater than an increased income potential. For both the control of confounding and the exploration of the socio-economic determinants of health, education is therefore generally used in analyses in addition to any available economic measures. This thesis has demonstrated that the magnitude of inequalities in stunting is similar whether the wealth index or education of the household head is used as the SEP indicator. This may imply that, despite the more wide-reaching causal pathways to health of education compared with purely economic measures, it may be more appropriate to use education in studies quantifying inequalities in health rather than using a poorly understood 'economic' indicator such as the wealth index. I would argue that where collection of full consumption expenditure data is not possible, using education to quantify inequalities would be preferable to using a wealth index. Although education is an intervention in its own right, the causal pathways between education and many health outcomes are well-studied, and are known to be at least partially economic. Thus researchers could be encouraged to emphasise that the reduction of health inequalities would be possible both through increasing education itself, and increasing the economic gains that are a mediator of the education-health relationship.

Participatory wealth ranking (PWR) techniques may be a valid alternative to the wealth index for studies being carried out over a relatively small area. The concepts of SEP determining the PWR hierarchy are perhaps no clearer than those determining the wealth index, and neither therefore are the policy implications. The process of carrying out PWR, however, involves qualitative data collection on concepts and indicators of SEP within the community. Respondents are asked to describe the characteristics of the households in each wealth group, facilitating a better understanding of the socio-economic processes leading to the PWR hierarchy. One major disadvantage of the PWR approach is that it is only possible within a relatively small geographical area. It is also considerably more resource-intensive than the wealth index. Where geographical area of the study is small, however, my view would be that the added complexity of data collection would be more than counter-balanced by the confidence that a locally-relevant concept of social stratification is being captured, and by the enhanced understanding of the determinants of the PWR rankings that the research process provides. Interestingly, however, not only does PWR correlate poorly with a wealth index generated using PCA, it also has weak correlation with an index where the survey indicators are assigned weights informed by PWR.[322]

Single-question subjective measures of SEP are a further possible alternative to the wealth index. The proportion of variance in these subjective measures explained by the key socio-economic indicators of education, consumption expenditure, and community infrastructure was lower than the proportion of variance in the wealth index explained by the same indicators. This reflects, however, the fact that subjective SEP is determined by a far wider range of factors than the main SEP indicators, as is well-established in the psychological literature. Allowing individuals to rate their own SEP requires the assumption that the questions are interpreted and understood in the same way by all respondents. It also has the possibility of introducing bias from people ranking themselves as lower than they actually are in the hope they will receive benefit from social support programmes. It does, however, have the key advantage of not imposing any outsider assumptions about what are the important aspects of living standards within a given setting. No former knowledge of judgements are required of what the relevant indicators of SEP are for a community, the community are allowed to decide for themselves. In order for these subjective measures of SEP to have any clearer interpretation and policy relevance than the wealth index, however, qualitative research would need to be undertaken in any given setting to gain an understanding of the reasons why individuals/households rank themselves in particular ways. This will certainly add to the resources required for using this type of indicator, but at least such research is possible. With a wealth index created using PCA, the importance of indicators is determined statistically and if formative research has not been used to select indicators initially there is limited potential for linking the wealth index to local concepts of SEP.

The choice of subjective SEP indicator will depend on the aims of the study; the economic ladder question (ELQ) had the strongest agreement with consumption expenditure of all the indicators explored in this thesis, so may be of most relevance if economic position is of particular interest. In my view, it also has more intuitive conceptual clarity than the measure of consumption adequacy. If consumption adequacy measures are used, I would favour the use of food consumption adequacy only, since the determinants of perceived adequacy of healthcare, housing, and clothing are likely to be considerably different to those of food. Again, however, the proposed causal mechanisms linking SEP to health in the study of interest would affect whether food consumption alone or a full consumption adequacy measure would be more appropriate. The measure of income sufficiency used in the Malawi IHS2 also has conceptual clarity, although in my view the number of categories used in this study was perhaps too great and could have lead to difficulty in responding to this question.

Using SEP indicators for controlling confounding presents different issues to an interest in quantifying inequalities or in exploring the socio-economic determinants of a health outcome. The aspects of SEP that may be particularly relevant for confounding may vary for each relationship under study and between settings. Using several SEP indicators is probably important for most studies. Given the considerable lack of agreement between the wealth index and other SEP indicators, and the fact that all SEP indicators explored in these analyses were associated with child height-for-age independently of the wealth index, relying solely on the wealth index to control for confounding by SEP seems unwise. Given the uncertainty surrounding the socio-economic processes being captured by the wealth index hierarchy, mapping out the causal assumptions between the wealth index and the exposure and outcomes of interest would be problematic.

Modelling the determinants of a health outcome with a goal of making causal inference requires a firm understanding of the underlying concepts being measured by each indicator, and for this reason the wealth index is unlikely to be a useful tool for this purpose.

The wealth index, and many of the alternative SEP indicators discussed above are household-level measures. Despite this, they are frequently used as individual-level indicators in analyses. This makes the assumption that all resources are pooled and equally distributed between household members. Intra-household differentials are ignored, although it is likely they are present along lines of gender, age, and position in the household. Unequal distribution of resources between household members may be the result of preferences, cultural traditions, discrimination, or efficiency. An understanding and consideration of these differentials is crucial for effective interventions. For instance, it is known that supplementary food given to a mother for a certain child will often be divided between other household members.[60] Arguably, therefore, individual-level policies require individual-level measures of SEP. It is also extremely important to remember that SEP is far from being the only social stratification process that is important for health. Health inequalities have been demonstrated according to gender, age, ethnicity, religion, and area over and above the effects of SEP.[198] A comprehensive social epidemiological study may, therefore, need to consider a range of social and economic factors aside from SEP.

11.4.5 Advantages and disadvantages to the wealth index

I now summarise the advantages and disadvantages of the wealth index approach, taking all of the above factors into consideration.

Advantages to the wealth index approach

1. Wealth indices can be constructed from the DHS and UNICEF MICS, unparalleled sources of high-quality, nationally-representative datasets from low- and middle-income countries
2. Data collection for a wealth index is simple, cheap, and requires minimal interview time (my experience from fieldwork in Ghana and Uganda is that the interview time for all wealth index questions together would be about one minute; the questions tend to generate very little discussion or require any elaboration)
3. Data collection may be less subject to recall bias than alternative SEP indicators
4. Data analysis is considerably simpler than for consumption expenditure
5. The wealth index has helped to increase the prominence of health inequalities on the global health agenda

Disadvantages of the wealth index

1. The concept of SEP being measured remains unclear, particularly in rural areas
2. The causal links to health and policy implications are uncertain
3. Does not permit locally-relevant concepts of SEP, unless formative research is conducted before selection of wealth index indicators
4. The wealth index makes the implicit ideological assumption that urbanisation and economic development are positive

11.5 Recommendations for future research

From the work carried out in this thesis, I have drawn several recommendations for using the wealth index in future research. Additionally, I have identified areas of suggested further methodological research on the wealth index approach.

Recommendations for using the wealth index as a measure of SEP

Issues for researchers deciding whether to use a wealth index:

1. Social epidemiology and its potential use to policy makers will be strengthened if researchers clearly define the social stratification processes they are attempting to measure and how they are hypothesised to be related to the health outcome under study.
2. Alternatives to the wealth index do exist for low- and middle-income research. Subjective measures, whilst having their own set of limitations, are equally quick and easy for data collection, more relevant to local concepts of SEP, and qualitative research can more readily be undertaken to understand their determinants. Similarly, where LSMS-type data exist, more accurate proxies for consumption expenditure can be derived using a short list of expenditure items if researchers wish to capture a purely economic concept of SEP.

Issues for researchers using a wealth index with pre-existing data

1. The use of PCA with dummy variables is not recommended; instead PCA should be used with ordinal variables treated as continuous terms, or if nominal variables must be included in the index then MCA should be used.
2. The wealth index should not be assumed to be a proxy for consumption expenditure, and it should be noted that the socio-economic processes underlying the wealth index hierarchy remain uncertain.

Issues specifically for researchers conducting primary research for a wealth index

1. The number and range of indicators used in DHS indices should not be used as standard. A greater number of relevant indicators is desirable since it will result in better differentiation between households. The choice of indicators should ideally be informed by formative research that identifies locally-applicable indicators of high SEP.

Areas of further research on the wealth index approach

The gaps in the existing literature, and the limitations of the analyses in this thesis highlight a number of important areas for future methodological research on the wealth index approach:

1. The issues in constructing a wealth index that I explored in Chapters 5-7 of this thesis would benefit from further exploration in datasets from other settings; this would strengthen the conclusions I have reached and facilitate more concrete recommendations.
2. Similarly, the role of household- versus community-level indicators as drivers of the wealth index hierarchy, and more generally the socio-economic processes underlying wealth index scores would be better understood if similar studies were conducted in datasets from different settings.
3. If subjective measures of SEP are to be more widely used in social epidemiology, an improved understanding of the processes contributing to people's rankings across different settings would be beneficial. This could be achieved through qualitative studies. Similarly, analyses of the pathways through which they affect health would contribute to their policy-relevance.

11.6 Final words

The wealth index was a tool developed for the analysis of existing datasets lacking in alternative economic indicators. In this role, it has proved extremely useful and important. It has been used to quantify and compare inequalities in a wide range of health, nutrition, and population outcomes across a wide range of low- and middle-income country settings. It has certainly contributed to the prominence of socio-economic inequalities on the global health agenda. The wealth index method has now been widely adopted by the research community and is extensively used in primary data collection. This extension of the approach is questionable, given the lack of understanding of the social stratification processes leading to wealth index hierarchies. In particular, the reliance on the indicators and methods used by the DHS as a 'standard' methodology is undesirable. Overall, my position is that the wealth index should be used only after careful consideration of the potential alterative SEP indicators, and on the understanding that it should not necessarily be viewed as a proxy for consumption expenditure, and neither is it clear how results should be interpreted or translated into policy. Further research into the socio-economic processes leading to wealth index hierarchies is necessary if use of the wealth index is to continue.

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Appendices

Appendix A: Distribution of the categorical variables in the Brazil 1996 DHS wealth index

Variable	*Frequency*	*Percent*
Water source		
piped into residence	8,547	64.39
piped in yard /plot	598	4.51
well /spring inside	1,843	13.88
well /spring outside	1,332	10.03
bottled water	498	3.75
other	456	3.44
Total	*13,274*	*100.00*
Toilet facility		
toilet to sewer	4,465	33.73
toilet to open space	619	4.68
toilet to river /lake	199	1.50
latrine to sewer	1,438	10.86
latrine no-connected	2,757	20.83
traditional latrine	2,048	15.47
no facility	1,710	12.92
other	2	0.02
Total	*13,238*	*100.00*
Floor material		
earth /sand	859	6.47
wood planks	899	6.77
polished wood	1,214	9.14
vinyl	82	0.62
ceramic tiles	3,566	26.86
cemento	6,153	46.34
carpet	400	3.01
other	104	0.78
Total	*13,277*	*100.00*
Main wall material		
palm, straw	33	0.25
mud unpolished	515	3.88
raw wood	428	3.22
alvenaria (finished)	11,027	83.07
polished wood	1,268	9.55
other	3	0.02
Total	*13,274*	*100.00*
Main roof material		
palm /straw	168	1.27
raw wood	61	0.46
clay tiles	7,240	54.53
concrete	3,490	26.29
zinc	514	3.87
polished wood	1,115	8.40
eternit, amianto	634	4.78
other	55	0.41
Total	*13,277*	*100.00*

Appendix B: Inequalities in stunting by area and wealth index construction

Table B.1: Inequalities in stunting in different areas, and using constructions of the wealth index excluding indicators with an urban bias

	% children stunted per quintile						
Index	Q1 (low)	Q2	Q3	Q4	Q5 (high)	p	RII (95% CI)
Core assets							
Whole population (n=11243)	44.9	44.9	51.2	42.3	36.5	<0.001	1.42 (1.16-1.75)
urban areas (n=1434)	47.5	36.5	52.0	50.9	37.8	0.26	1.74 (0.89-3.37)
peri-urban areas (n=739)	33.1	42.8	50.2	31.9	35.9	0.59	1.15 (0.53-2.48)
rural areas (n=9070)	45.3	45.1	51.1	42.5	35.4	0.0002	1.30 (1.02-1.65)
Excluding electricity							
Whole population (n=11257)	44.9	45.1	51.0	42.2	36.5	<0.001	1.43 (1.17-1.76)
urban areas (n=1434)	47.5	36.2	52.0	50.9	37.8	0.26	1.74 (0.89-3.39)
peri-urban areas (n=739)	33.1	43.1	50.2	32.2	34.7	0.61	1.16 (0.54-2.51)
rural areas (n=9084)	45.3	45.3	51.0	42.4	35.5	0.0003	1.31 (1.03-1.66)
Excluding electricity and consumer durables dependent on it							
Whole population (n=11264)	44.8	46.9	43.9	44.6	36.5	0.0002	1.41 (1.14-1.75)
urban areas (n=1436)	50.3	54.0	40.1	48.2	35.3	0.082	2.70 (1.16-6.25)
peri-urban areas (n=739)	35.2	46.9	30.0	31.7	36.4	0.52	1.11 (0.55-2..27)
rural areas (n=9089)	45.0	46.7	44.4	45.3	37.7	0.056	1.24 (0.96-1.59)
Excluding community-level services							
Whole population (n=11271)	46.8	46.0	44.5	42.9	35.7	<0.001	1.64 (1.31-2.04)
urban areas (n=1438)	39.4	57.9	41.4	52.1	36.8	0.073	1.90 (0.96-3.76)
peri-urban areas (n=740)	41.9	45.0	32.1	28.5	35.4	0.42	1.51 (0.55-4.12)
rural areas (n=9093)	47.2	45.9	45.0	43.0	34.1	0.0027	1.52 (1.18-1.96)
Excluding housing-related items							
Whole population (n=11245)	44.7	43.8	47.8	44.8	37.6	0.0018	1.27 (1.02-1.57)
urban areas (n=1434)	49.1	33.6	32.7	48.2	38.5	0.50	1.51 (0.77-2.95)
peri-urban areas (n=739)	32.5	35.5	47.9	44.1	31.8	0.48	1.09 (0.50-2.39)
rural areas (n=9072)	45.1	44.1	47.9	44.7	39.0	0.15	1.11 (0.86-1.44)

Appendix C: Additional indicators used to construct wealth indices for Chapter 7

Table C.1: Descriptive statistics of productive assets

Indicator	Prevalence, or mean (SE)				% missing
	Whole population (N=11,280)	Urban areas (N=1,440)	Peri-urban areas (N=740)	Rural areas (N=9,100)	
Sewing machine	2.8	4.2	4.4	2.5	0
Ox-cart	2.0	0.35	1.8	2.3	0
Wheelbarrow	2.8	7.2	6.4	1.8	0
Hand-sprayer	1.6	1.9	1.8	1.5	0
Cattle (number of)	0.345 (0.0245)	0.124 (0.0641)	0.368 (0.0989)	0.353 (0.0268)	37.3
Chickens (number of)	7.38 (0.715)	37.0 (24.5)	6.23 (0.413)	6.50 (0.157)	37.3
Other poultry (number of)	1.35 (0.0717)	2.20 (0.889)	1.59 (0.318)	1.30 (0.0707)	37.3
Goats (number of)	2.08 (0.444)	1.04 (0.189)	1.00 (0.161)	2.19 (0.489)	37.3
Sheep (number of)	0.0498 (0.00697)	0 (0)	0.0411 (0.0284)	0.0521 (0.00745)	37.3
Pigs (number of)	1.81 (1.49)	0.114 (0.0498)	0.430 (0.188)	1.96 (1.64)	37.3
Other livestock (number of)	0.0604 (0.0118)	0.0948 (0.0955)	0.0368 (0.0325)	0.0609 (0.0124)	40.0
Area of land owned	0.996 (0.0178)	0.321 (0.0337)	0.757 (0.0765)	1.13 (0.0208)	2.1

Table C.2: Descriptive statistics of additional consumer durables and services

Asset	% households with the asset				% Missing
	Whole population (N=11,280)	Major urban centres (N=1,440)	Peri-urban areas (N=740)	Rural areas (N=9,100)	
Lighting fuel					
Collected firewood/grass	7.5	1.3	3.9	8.8	0.044
Purchased firewood	0.27	0.46	0.25	0.24	
Paraffin/diesel/gas	84.4	55.8	79.5	89.4	
Electricity	6.0	33.2	12.6	1.1	
Batteries/candles/matches/ Other	1.9	9.1	3.7	0.54	
Any household members sleep under a bed-net	38.5	46.9	60.2	35.4	0.080
Bed	30.6	63.9	51.0	23.6	0
Table	35.1	56.5	48.0	30.7	0
Chair	44.0	60.4	58.9	40.1	0
Tape-player, CD-player, or HiFi	16.2	41.8	26.1	11.3	0
Fan	2.5	13.6	5.8	0.44	0
Sewing machine	2.8	4.2	4.4	2.5	0
Refrigerator	2.1	11.6	3.6	0.43	0
Upholstered chair/sofa	44.0	60.4	58.9	40.1	0
Coffee table	11.5	43.8	19.6	5.7	0
Cupboard, drawers or bureau	7.9	23.8	16.0	4.6	0
Desk	0.79	3.3	0	0.46	0
Clock	19.7	49.1	33.9	13.8	0
Iron (clothes)	20.4	44.6	31.3	15.6	0
Working landline phone in home	0.91	5.5	1.2	0.15	0.089
Working cellphone in home	3.2	17.8	5.7	0.60	0.14
Number of rooms in dwelling					
0	1.4	0.29	1.2	1.6	0.15
1	21.1	24.6	16.5	20.9	
2	34.3	34.7	33.8	34.2	
3 or more	43.3	40.4	48.5	43.3	

Asset	% households with the asset				% Missing
	Whole population (N=11,280)	Major urban centres (N=1,440)	Peri-urban areas (N=740)	Rural areas (N=9,100)	
Material of roof is modern (not traditional)	27.0	78.7	44.4	17.2	0
Rubbish disposal facilities					
Collected from rubbish pit	3.0	16.2	2.3	0.92	0.12
Rubbish pit	49.0	44.8	65.3	48.4	
Burning	7.1	7.5	5.6	7.1	
Public rubbish heap	19.8	24.7	16.7	19.3	
Other	3.3	0.98	0.98	3.8	
None	17.9	5.8	9.2	20.5	
Crowding score[8] [mean (SE)]	0.693 (0.00746)	0.719 (0.0214)	0.763 (0.0423)	0.683 (0.00858)	0.15
Mortar & pestle	48.6	29.1	49.3	51.7	0

[8] Number of rooms in dwelling divided by number of household members

Table C.3: Descriptive statistics of human capital and demographic indicators

Asset	% households with the asset				% Missing
	Whole population (N=11,280)	Major urban centres (N=1,440)	Peri-urban areas (N=740)	Rural areas (N=9,100)	
Highest educational grade of household head					
None/pre-school only	27.7	9.1	21.4	31.2	0.35
Partial primary	42.7	25.1	37.9	45.9	
Completed primary	12.3	18.3	11.4	11.4	
Partial secondary	15.7	40.7	26.9	10.8	
Higher education	1.7	6.7	2.4	0.77	
Religion of household head					
None	5.6	3.4	3.1	6.2	0.12
Traditional	1.6	0.58	0.17	1.8	
Islam	13.8	11.8	14.5	14.1	
Catholic	20.1	22.0	19.6	19.8	
CCAP	15.9	21.1	17.7	14.9	
Other Christian	43.2	41.2	45.0	43.3	
Marital status of household head					
Monogomous marriage	63.9	69.8	63.2	63.0	0.62
Polygamous marriage	9.2	3.1	7.2	10.3	
Divorced/separated	11.5	7.4	11.0	12.2	
Widowed	12.2	8.8	13.1	12.6	
Never married	3.3	11.0	5.5	1.9	
Language spoken at home					
Chichewa	59.7	83.9	57.9	56.0	0.20
Nyanja	11.3	3.8	9.8	12.6	
Yao	9.4	2.0	9.1	10.6	
Tumbuku	7.7	6.2	7.0	8.0	
Other	11.8	4.1	16.2	12.7	
Highest qualification of household head					
None	76.6	42.9	64.4	83.0	0.52
PSLC	9.7	15.4	12.0	8.6	
JCE	7.8	17.6	13.1	5.8	
MSCE	4.5	16.9	8.5	2.2	
Diploma or higher	1.4	7.2	2.0	0.44	
Female-headed household	22.9	14.9	23.1	24.2	0
Household age [mean (SE)]	42.4 (0.181)	37.2 (0.557)	41.0 (0.797)	43.4 (0.194)	0.53
Household head can read one page letter in Chichewa	64.8	86.3	73.7	60.6	0.19
Household head can read one page letter in English	35.3	65.7	49.4	29.2	0.23

Table C.4: Descriptive statistics of subjective well-being indicators

Asset	% households with the asset				% Missing
	Whole population (N=11,280)	Major urban centres (N=1,440)	Peri-urban areas (N=740)	Rural areas (N=9,100)	
Adequacy of food consumption					
Less than adequate	56.6	48.3	49.5	58.6	0.053
Just adequate	37.5	48.1	46.8	35.0	
More than adequate	5.9	3.6	3.8	6.4	
Adequacy of housing					
Less than adequate	52.4	44.1	49.2	54.0	0.062
Just adequate	42.6	52.2	46.4	40.7	
More than adequate	5.0	3.7	4.4	5.3	
Adequacy of clothing					
Less than adequate	71.8	56.1	60.8	75.3	0.071
Just adequate	26.3	41.8	37.5	22.9	
More than adequate	1.8	2.2	1.8	1.8	
Adequacy of healthcare					
Less than adequate	60.3	53.4	47.5	62.4	0.089
Just adequate	36.4	44.5	50.6	33.9	
More than adequate	3.4	2.1	1.8	3.7	
Economic Ladder Question					
Step 1	45.8	25.9	34.6	49.9	0.15
Step 2	38.4	40.7	45.3	37.5	
Step 3	12.8	24.6	16.7	10.6	
Step 4 or above	3.0	8.8	3.4	2.0	
Income adequacy					
Allows you to build savings	2.1	5.7	4.8	1.3	0.080
Allows you to save a little	8.2	7.9	8.1	8.2	
Just enough	25.2	40.7	28.3	22.4	
Not enough, use savings	13.0	22.4	10.0	11.7	
Not enough, must borrow	51.6	23.3	48.8	56.4	
Life satisfaction					
Very unsatisfied	24.8	36.3	11.4	24.1	0.071
Unsatisfied	38.6	15.7	34.3	42.7	
Neither unsatisfied nor satisfied	13.3	19.9	15.9	12.0	
Satisfied	17.9	20.6	27.4	16.7	
Very satisfied	5.4	7.6	11.1	4.5	
# Changes of clothes [mean (SE)]	4.66 (0.0367)	6.19 (0.0868)	5.28 (0.169)	4.36 (0.0421)	0.19

Asset	% households with the asset				% Missing
	Whole population (N=11,280)	Major urban centres (N=1,440)	Peri-urban areas (N=740)	Rural areas (N=9,100)	
Sleeping place					
Bed and mattress	18.8	55.1	33.0	11.8	0.062
Bed and mat	9.0	6.1	13.2	9.1	
Bed alone	1.8	1.9	2.0	1.8	
Mattress on floor	4.1	8.2	4.1	3.4	
Mat (grass) on floor	64.5	28.3	46.6	71.8	
Floor/cloth/other	1.9	0.28	1.2	2.2	
Sleeping in cold season					
Blanket and sheet	20.3	46.9	38.5	14.6	0.062
Blanket alone	68.1	50.2	55.6	72.1	
Sheet alone	2.1	1.5	1.9	2.2	
Cloth/clothes/nothing	9.4	1.5	4.1	11.1	

Appendix D: Inequalities in stunting when different indicators are used to construct the wealth index

Table D.1: Observed inequalities in stunting using wealth index including productive assets

	% children stunted per quintile						
Index	**Q1 (low)**	**Q2**	**Q3**	**Q4**	**Q5 (high)**	**p**	**RII (95% CI)**
Core assets							
Whole population (n=11243)	44.9	44.9	51.2	42.3	36.5	<0.001	1.42 (1.16-1.75)
urban areas (n=1434)	47.5	36.5	52.0	50.9	37.8	0.26	1.74 (0.89-3.37)
peri-urban areas (n=739)	33.1	42.8	50.2	31.9	35.9	0.59	1.15 (0.53-2.48)
rural areas (n=9070)	45.3	45.1	51.1	42.5	35.4	0.0002	1.30 (1.02-1.65)
Including productive assets							
Whole population (n=7057)	48.0	44.7	46.4	45.9	37.5	0.0010	1.46 (1.14-1.87)
urban areas (n=257)	51.4	46.3	44.7	51.5	35.6	0.67	2.22 (0.55-8.95)
peri-urban areas (n=431)	28.3	40.9	35.5	37.5	35.7	0.90	0.89 (0.39-2.02)
rural areas (n=6369)	48.6	44.8	46.8	46.0	38.2	0.0061	1.42 (1.09-1.85)
Including additional assets							
Whole population (n=11182)	46.8	45.7	45.7	43.6	34.5	<0.001	1.69 (1.37-2.08)
urban areas (n=1430)	52.7	41.9	44.2	50.1	36.9	0.18	2.37 (0.77-7.27)
peri-urban areas (n=736)	52.2	39.8	29.7	36.4	32.1	0.087	2.13 (0.92-4.91)
rural areas (n=9016)	46.6	45.9	46.4	43.5	32.8	<0.001	1.55 (1.23-1.95)
Including highest educational grade of household head							
Whole population (n=11203)	45.4	45.8	47.5	42.6	35.7	<0.001	1.55 (1.25-1.92)
urban areas (n=1430)	48.1	36.2	39.5	56.8	36.8	0.033	2.06 (0.97-4.36)
peri-urban areas (n=737)	38.5	38.2	38.9	32.8	35.0	0.95	1.25 (1.13-1.85)
rural areas (n=9036)	0.46	0.46	0.48	0.42	0.34	0.0003	
Including full set of human capital variables							
Whole population (n=11153)	45.9	46.0	47.0	43.5	35.0	<0.001	1.64 (1.32-2.04
urban areas (n=1423)	43.6	39.6	65.7	45.8	35.8	0.0015	3.34 (1.36-8.81)
peri-urban areas (n=733)	40.2	44.1	31.7	39.6	32.7	0.57	1.56 (0.81-3.02)
rural areas (n=8997)	46.1	46.1	47.0	43.5	35.1	0.0003	1.48 (1.16-1.89)

% children stunted per quintile							
Index	Q1 (low)	Q2	Q3	Q4	Q5 (high)	p	RII (95% CI)
Including food consumption adequacy							
Whole population (n=11203)	46.5	47.7	43.4	43.6	35.8	<0.001	1.65 (1.34-2.04)
urban areas (n=1430)	44.5	48.8	45.8	53.9	36.9	0.13	2.21 (1.04-4.70
Peri-urban areas (n=737)	38.7	39.4	32.9	35.9	34.5	0.95	1.25 (0.52-2.96)
rural areas (n=9036)	46.7	47.9	43.7	43.3	34.9	0.0004	1.57 (1.23-2.00)
Including full set of subjective well-being indicators							
Whole population (n=11153)	47.9	45.9	47.5	40.4	35.4	<0.001	1.84 (1.49-2.27)
urban areas (n=1423)	45.6	56.0	55.0	37.8	37.1	0.096	3.37 (1.14-9.38)
peri-urban areas (n=733)	49.7	30.4	39.8	37.6	32.7	0.34	1.65 (0.77-3.53)
rural areas (n=8997)	47.8	46.1	47.4	40.9	35.0	<0.001	1.72 (1.37-2.17)

Appendix E: Recoding continuous variables to generate community infrastructure variable

Availability of piped water
The proportion of households with an piped water supply (either piped into or outside of residences) was generated using household-level aggregates. Almost 80% of communities have no households with access to piped water (**Figure AXa**). A dichotomised variable was therefore created where 0 = no households have piped water, and 1 = some households have piped water.

Availability of electricity
The proportion of households with an electricity supply was generated using household-level aggregates. Almost 80% of households live in a community where nobody has access to electricity (**Figure AXb**). A dichotomised variable was created where 0 = no households in community have electricity, and 1 = some households in community have electricity

Access to sanitation facilities
The proportion of households with access to any toilet facilities was generated using household-level aggregates. Over 30% of households live in a community where everybody has access to some form of sanitation facility (**Figure AXc**). A dichotomised variable was created where 0 = not every household has toilet facilities, and 1 = every household has toilet facilities

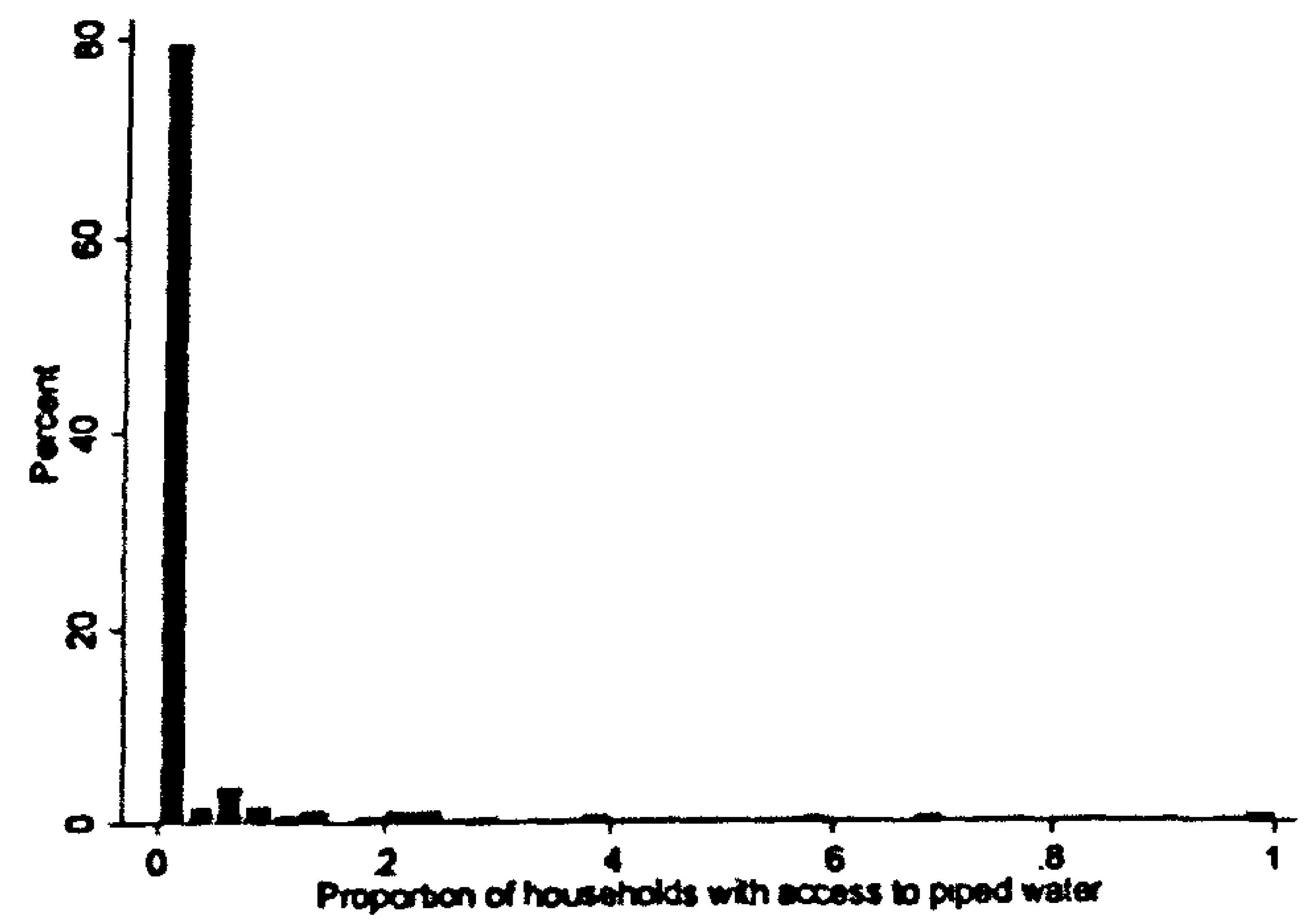
Tar/asphalt roads
The distance to the nearest tar/asphalt road was estimated by respondents to the community questionnaire. Almost 20% of households live in a community with a tar/asphalt road in it (**Figure AXd**). A dichotomised variable was created where 0 = no tar/asphalt road within community, and 1 = tar/asphalt road in community.

Distance to a government primary school
The distance to the nearest government primary school was estimated by respondents to the community questionnaire. More than 40% of communities have a government primary school within them (**Figure AXe**). A dichotomised variable was created where 0 = no primary school in community, and 1 = primary school in community.

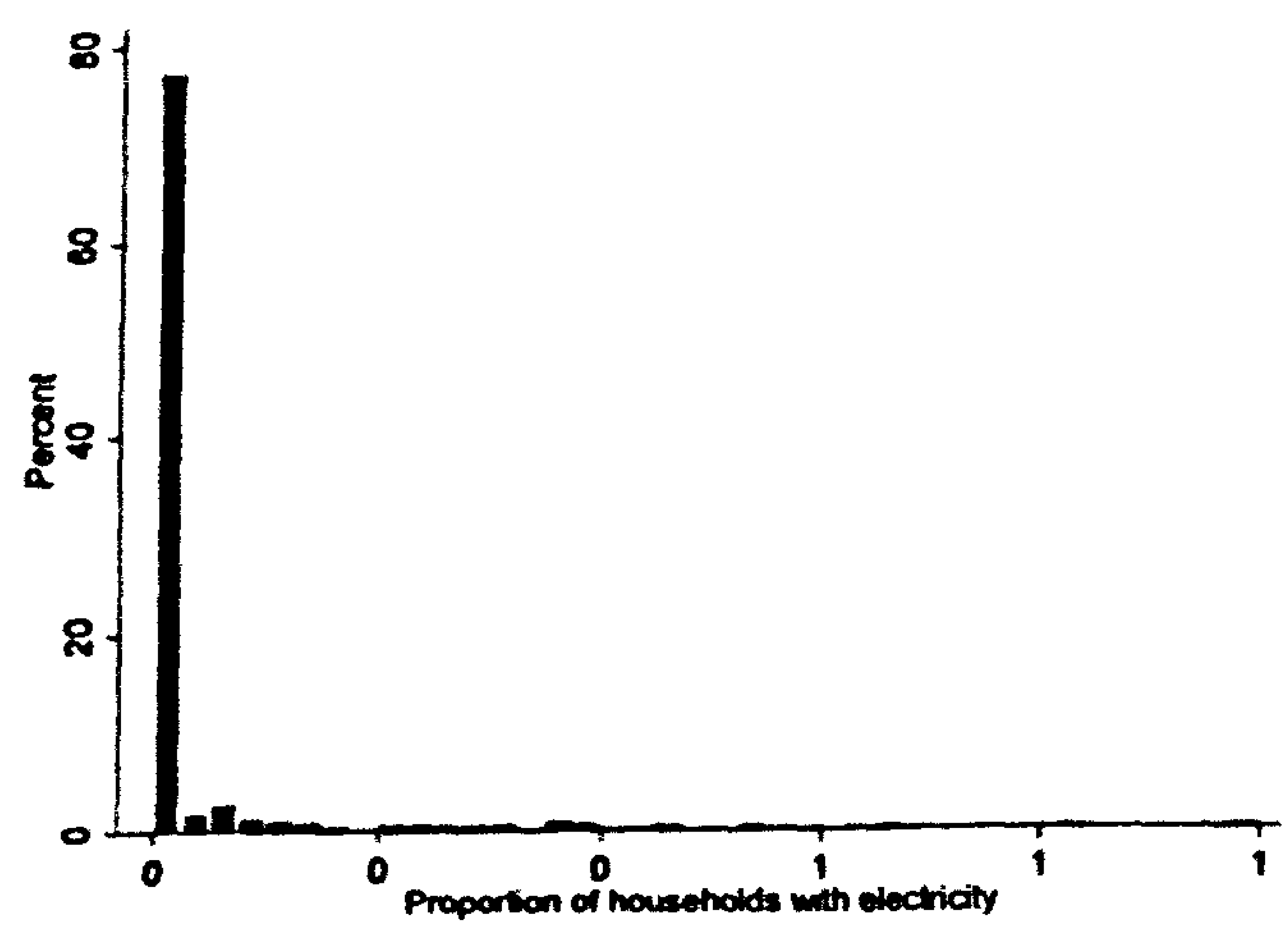
Distance to a government secondary school
The distance to the nearest government secondary school was estimated by respondents to the community questionnaire. Almost 25% of communities have a government secondary school within them (**Figure AXf**). A dichotomised variable was created where 0 = no secondary school in community, and 1 = secondary school in community.

Figure E.1: Distribution of community infrastructure indicators

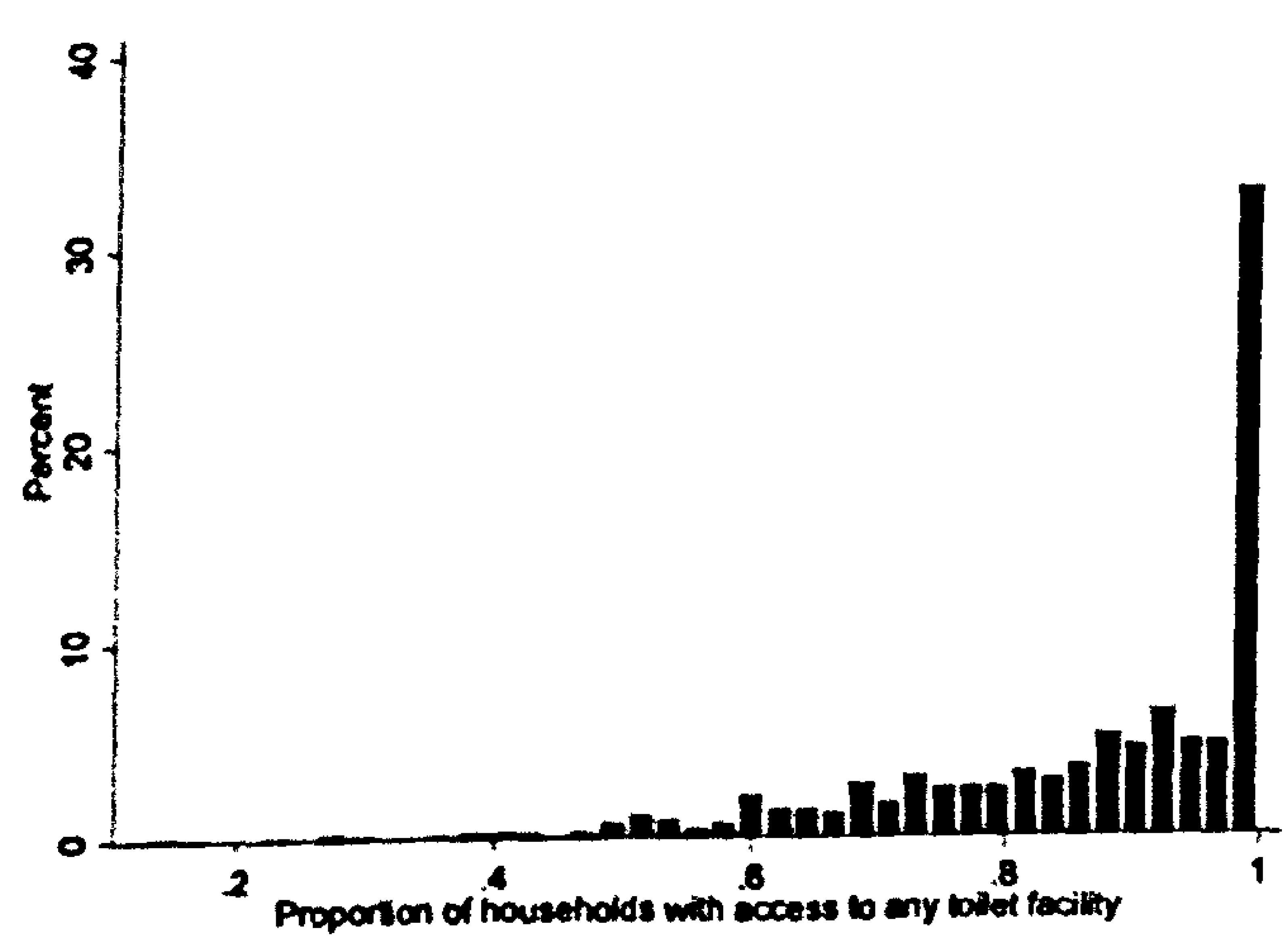
A: Proportion of households with access to piped water across communities



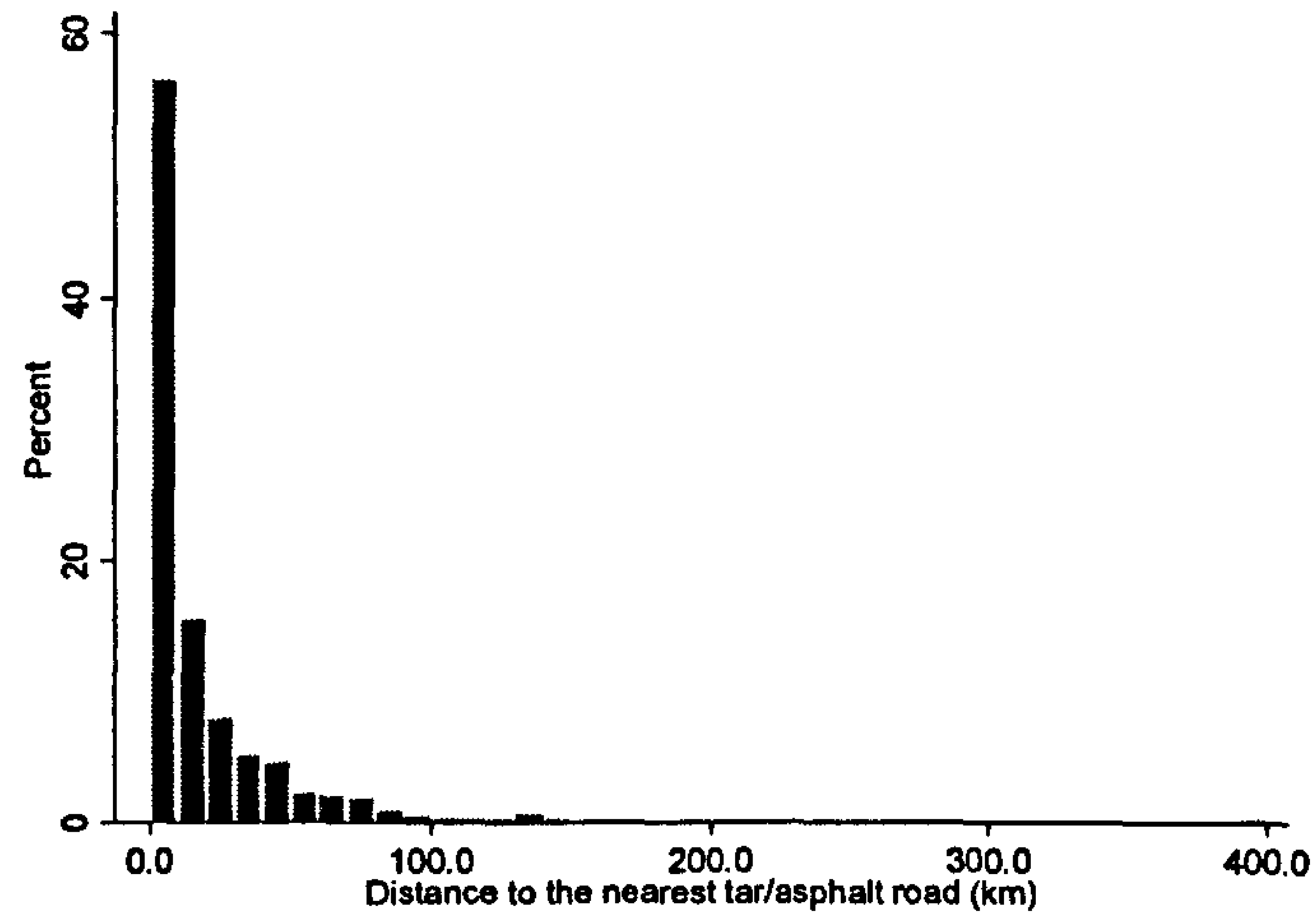
B: Proportion of households in a community with electricity:



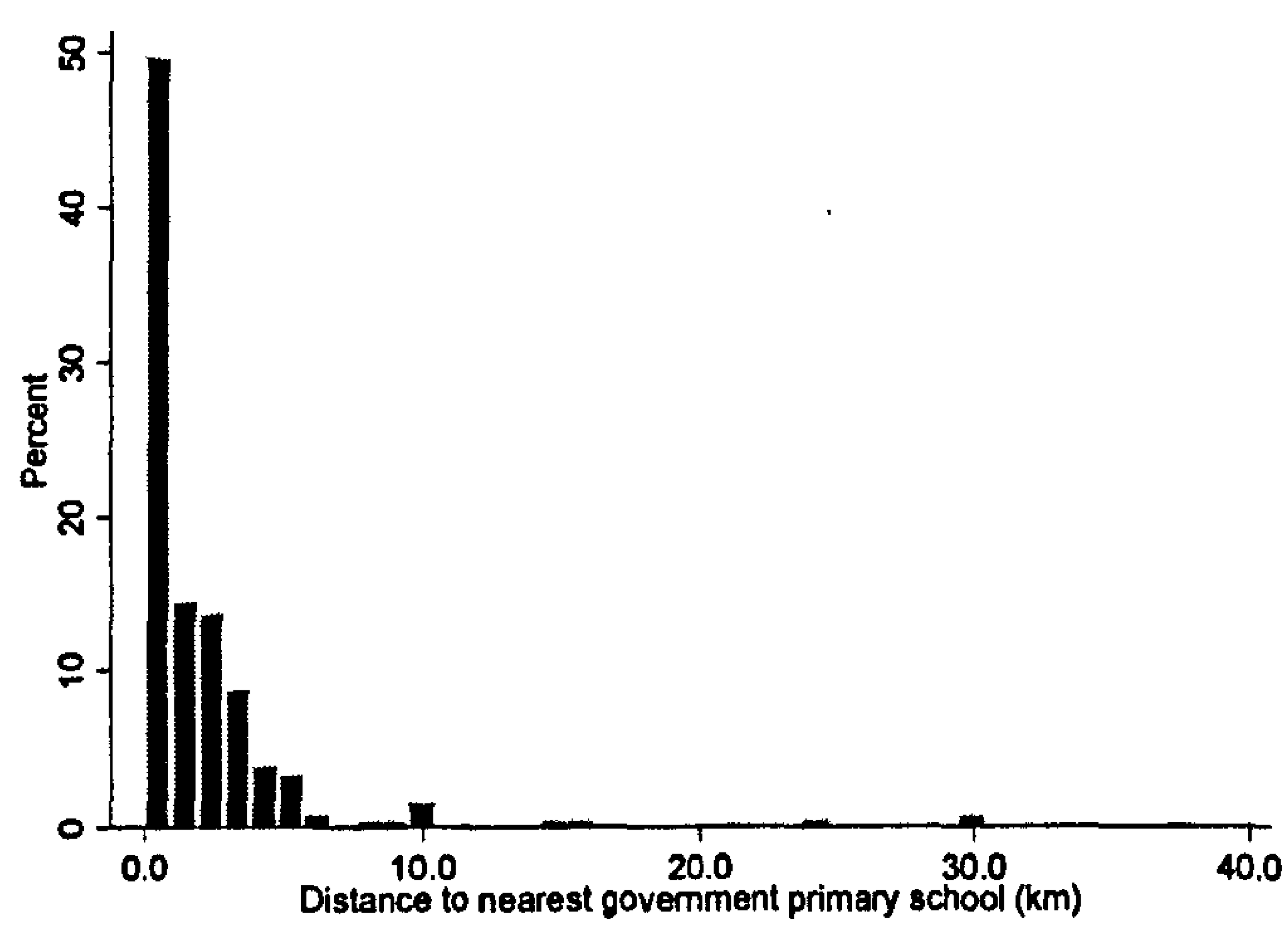
C: Proportion of households with any toilet facility across communities:



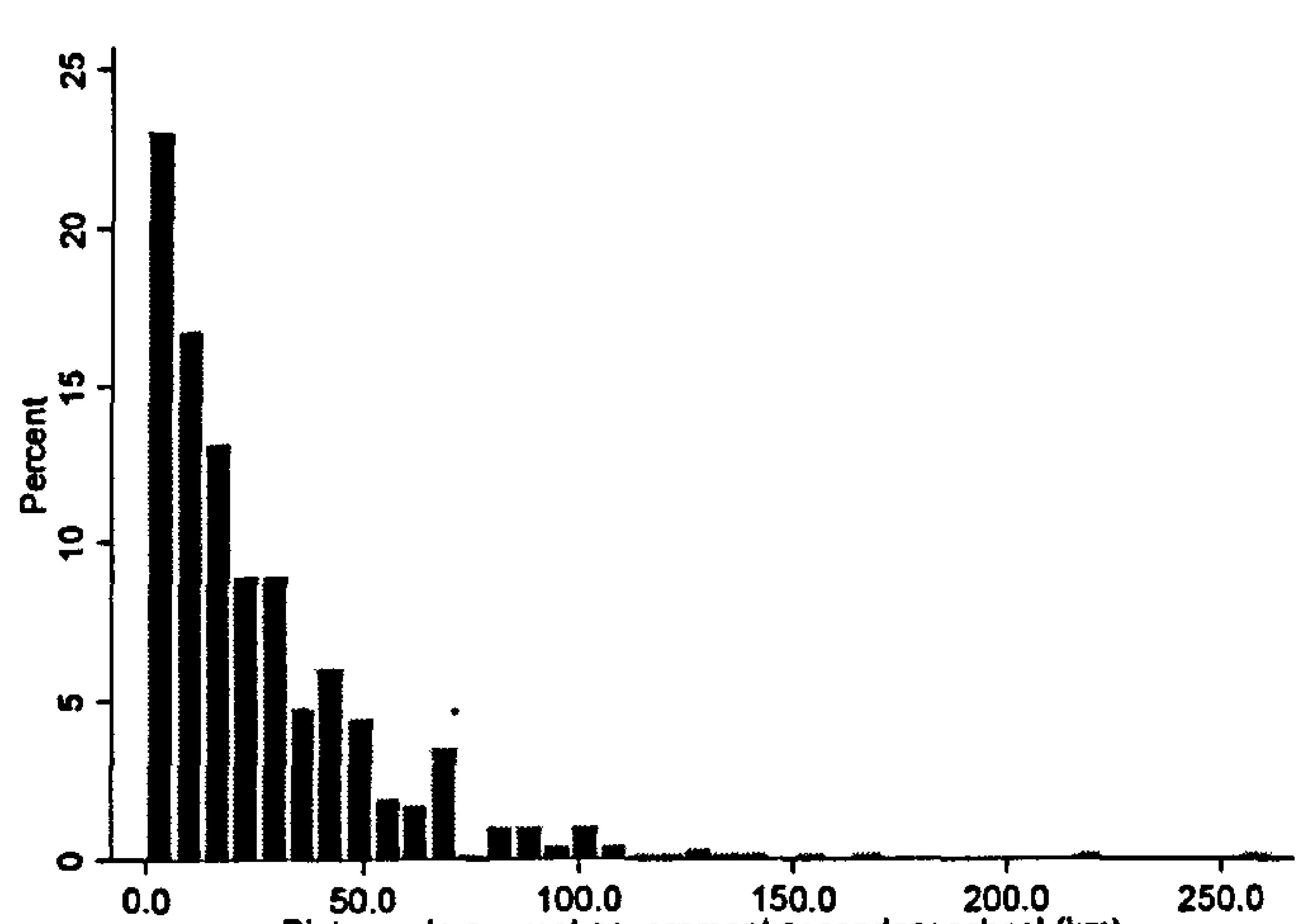
D: Distance to nearest tar/asphalt road in km:



E: Distance to the nearest primary school in km:



F: Distance to nearest government secondary school in km:



Appendix F: Correlations between variables in path models of determinants of the wealth index

Table F.1: Correlations between variables in path models of determinants of the wealth index

A: Full sample

	Quintiles of the wealth index	Log per capita consumption expenditures	Community infrastructure	Peri-urban areas	Rural areas	Primary education	Above primary education
Quintiles of the wealth index							
Log per capita consumption expenditures	0.402						
Community infrastructure	0.544	0.342					
Peri-urban areas	0.161	0.085	0.224				
Rural areas	-0.528	-0.321	-0.629	-0.527			
Primary education	-0.075	-0.095	-0.096	-0.027	0.094		
Above primary education	0.380	0.367	0.333	0.075	-0.314	-0.504	

B: Rural areas

	Quintiles of the wealth index	Log per capita consumption expenditures	Community infrastructure	Primary education	Above primary education
Quintiles of the wealth index					
Log per capita consumption expenditures	0.224				
Community infrastructure	0.213	0.109			
Primary education	-0.004	-0.005	-0.004		
Above primary education	0.205	0.221	0.110	-0.415	

C: Peri-urban (above the diagonal) and urban (below the diagonal) areas

	Quintiles of the wealth index	**Log per capita consumption expenditures**	**Community infrastructure**	**Primary education**	**Above primary education**
Quintiles of the wealth index		0.501	0.539	-0.112	0.496
Log per capita consumption expenditures	0.652		0.267	-0.111	0.372
Community infrastructure	0.658	0.343		-0.106	0.300
Primary education	-0.230	-0.309	-0.201		-0.623
Above primary education	0.470	0.437	0.271	-0.828	

Table F.2: Correlations in model of determinants of the wealth index excluding community-level indicators

	Wealth index excluding community indicators	Log of per capita expenditures	Community infrastructure	Peri-urban areas	Rural areas	Primary education	Higher than primary education
Wealth index excluding community indicators							
Log of per capita expenditures	0.425						
Community infrastructure	0.536	0.343					
Peri-urban areas	0.164	0.085	0.224				
Rural areas	-0.533	-0.322	-0.629	-0.527			
Primary education	-0.039	-0.095	-0.095	-0.025	0.094		
Higher than primary education	0.394	0.366	0.332	0.076	-0.314	-0.505	

Appendix G: Correlations between variables in path models of determinants of alternative SEP indicators

Table G.1: Correlations between variables in the models of determinants of consumption adequacy (below diagonal) and the economic ladder question (above diagonal)

	Consumption adequacy	Log of per capita expenditures	Community infrastructure	Peri-urban areas	Rural areas	Primary education	Higher than primary education
Ladder of subjective well-being		0.363	0.240	0.061	-0.224	-0.033	0.327
Log of per capita expenditures	0.278		0.344	0.085	-0.322	-0.095	0.366
Community infrastructure	0.196	0.343		0.225	-0.628	-0.095	0.322
Peri-urban areas	0.066	0.086	0.224		-0.528	-0.028	0.076
Rural areas	-0.127	-0.322	-0.628	-0.527		0.094	-0.313
Primary education	-0.040	-0.095	-0.095	-0.028	0.094		-0.505
Higher than primary education	0.210	0.366	0.332	0.076	-0.314	-0.505	

Table G.2: Correlations between variables in the models of determinants of food consumption adequacy (below diagonal) and income sufficiency (above diagonal)

	Food consumption adequacy	Log of per capita expenditures	Community infrastructure	Peri-urban areas	Rural areas	Primary education	Higher than primary education
Income sufficiency		0.171	0.266	0.008	-0.079	-0.023	0.084
Log of per capita expenditures	0.167		0.269	0.013	-0.070	-0.028	0.084
Community infrastructure	0.167	0.268		0.072	-0.323	-0.062	0.164
Peri-urban areas	0.008	0.012	0.072		-0.049	-0.003	0.007
Rural areas	-0.025	-0.081	-0.323	-0.052		0.019	-0.047
Primary education	-0.008	-0.028	-0.062	-0.003	0.019		-0.095
Higher than primary education	0.072	0.082	0.165	0.007	-0.047	-0.095	

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