Catastrophic Health Payments: Does the Equivalence Scale Matter?[1]

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today

We present a revised method for estimating equivalence scales. Such scales are used to adjust household welfare to account for the size of the household, and are used extensively in the application of the World Health Organization's (WHO) methodology for the evaluation of catastrophic health payments (Xu, 2005). Applications of the WHO method are underpinned by early estimates (Xu *et al.*, 2003) that do not control for household income, and, therefore, are likely to overstate equivalence. Thus, in addition to revising the method, we update the scale estimates for one country, South Africa, using more recent data. South Africa is considered, because the end of Aparthied has led to extensive social and economic changes that have influenced household structure and, presumably, equivalence. We also present information on the possible degree to which earlier estimates are overstated, as well as the effect that has on other components of the WHO method, especially the determinants of out-of-pocket expenditures and catastrophic health payments. We find that, in the worst case, initial estimates could be overstated by as much 46%, leading to the understatment of poverty lines by as as much as 17%. Despite these large differences, the average incidence of catastrophe in health expenditure was largely unaffected. Instead, differences in scales affect conclusions related to the determinants of out-of-pocket payments and catastrophic health expenditures, as well as the distribution of catastrophe across household size. Given that South Africa has low levels of catastrophic health expenditure, the effect could be even larger in other countries, and, therefore, we recommend that researchers consider a range of scales, when examining catastrophic health expenditures.

Introduction

The equivalence scale is an important component of the financial risk protection and health equity literature, because it is used to determine poverty lines within a country (Xu, 2005; Xu *et al.*, 2003). Given the structure of the WHO method (Xu, 2005), discussed below, those poverty lines are comparable across countries, and, therefore, the resulting financial risk measures, such as catastrophic health expenditure and impoverishment, are comparable across countries; it is not necessary to adjust incomes across countries using purchasing

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power parity or exchange rates, for example. As the WHO method is well-established, it is commonly applied. Recent research, for example, is available for Viet Nam (Van Minh *et al.*, 2013), Kenya (Buigut *et al.*, 2015), China (Y. Li *et al.*, 2014), India (Misra *et al.*, 2015), Nigeria (J. O. E. Ataguba, 2012), South Africa (Harris *et al.*, 2011) and Zambia (Masiye *et al.*, 2016), amongst others.

However, researchers have not queried the scale they have used, assuming, instead, that Xu et al.'s initial estimate (0.56) remains appropriate. However, if the scale estimate is incorrect, estimates of the poverty line, subsistence spending in the household, and, therefore, estimates of capacity-to-pay could be incorrect. If any of those are incorrect, reported catastrophic health expenditure and social determinants of such expenditure could be incorrectly estimated, too. Therefore, we investigate both the relevance of Xu et al.'s initial estimate and the degree to which its value filters through to estimates of catastrophic health expenditure.

We focus our attention on South Africa, and we follow the WHO method (Xu, 2005). We do so, because the initial estimates (Xu *et al.*, 2003) underpinning the method incorporate 1993 data - now one-quarter century old - from South Africa. It is reasonable to assume that South Africa, and the world, have changed in that period. For South Africa, in particular, the 1993 data was collected one year before the complete dismantling of the Apartheid regime. That regime separated economic opportunities and living areas by race, and controlled movement in the country through pass laws. In terms of changes, Wittenberg and Collison (2008), for example, show that households were nearly one person smaller in 2003 than in 1992, in at least one area of South Africa, while Leibbrandt and Levinsohn (2011) suggest a larger national decline occurred between 1993 and 2008. The intervening period corresponds to the rise of supermarkets in the country, along with lower food costs (D'Haese and Van Huylenbroek, 2005). Given such a large change in household structure and food availability, household food purchase behaviour, which is an integral component of equivalence estimation, has also changed. Thus, it is reasonable to assume that the initial estimate of equivalence may no longer be representative of South Africa.

Equivalence is underpinned by the idea that the share of food expenditure in the household budget is a useful indicator of household welfare (Deaton, 1987; Engel, 1857). Intuitively, the scale measures the proportional increase in household expenditure relative to the increase in household size. Economies of scale arise if larger households can make bulk purchases, for example, such that the proportionate increase in expenditure is less than unity, which would yield an equivalence scale that is also less than unity. In developing the analysis, as already noted, welfare is the share of the household budget allocated to food; however, as Nicholson (1976) notes, Engel (1857) -type equivalence scales are likely to over-estimate the cost of a child, since children, especially young children, primarily consume only food and clothing. Furthermore, such methods ignore behavioural aspects associated with childbirth.[3] Finally, estimating equivalence scales following the Engel method is complicated by the fact that equivalence is not observed, and, therefore, must be indirectly estimated. The Xu *et al.* (2003) approach simplifies Engel's argument. Rather than using the food share to determine household welfare, they use (equivalized per capita) food consumption. Although the simplification results in a model that is easier to estimate than the Engel-type equivalence scale, it is unlikely to provide an appropriate estimate of equivalence. In particular, larger households buy more food, and spend more in total. Not accounting for that fact potentially yields biased estimates.

Thus, we update the initial scale estimate with more recent data providing the most recent estimates available for the country. Although Posel *et al.* (2016) examine the effect of a range of hypothesized scale values on poverty rates, they do not estimate the scales. In addition to updating the estimates for South Africa, we develop an alternative formulation, following the literature on base-independent equivalence (Blackorby and Donaldson, 1993; Blundell and Lewbel, 1991; and Donaldson and Pendakur, 2003; Lewbel, 1989; Pendakur, 1999), and we estimate this alternative via semiparametric methods, originally proposed by (Yatchew *et al.*, 2003). As expected, we find that equivalence scales in South Africa are no longer similar to those estimated by Xu *et al.* (2003); South Africa has changed, and so

[3] Presumably, households that plan to have a (another) child, believe such an addition to the household will bring both joy and additional costs. Since equivalence scales generally only focus on costs, they are likely to further overstate the (net) cost of children.

has its households' behaviours. Our estimates suggest smaller scales, regardless of method. In some cases, the reduction is nearly 50%. These reduced scales yield increased poverty lines, up to 17%. However, the increased poverty line has very little impact on the average subsistence level, capacity-to-pay or catastrophic health expenditure incident. In other words, the choice of equivalence scale does not directly impact broad conclusions about financial risk protection in the country, when it comes to health care. However, because those scales account for household size, their values do affect conclusions related to the joint distribution of health care catastrophe and household size. For that reason, we recommend researchers report financial risk protection results across a range of equivalence scales.

Methods

Out-of-pocket payments and total expenditures are extracted from the 2010/11 South African Income and Expenditure Survey (Statistics South Africa, 2013) following the World Health Organization methodology (Xu, 2005). This data is used to estimate equivalence scales, following linear and semiparametric methods, along with catastrophic health expenditure. Given South Africa's apartheid history, we also extract the race of the household head to see whether or not equivalence scales and effects differ across population group. Finally, we consider the determinants of catastrophic health expenditure, to see how they are impacted by the choice of equivalence scale.

WHO Methodology

Although well described by Xu (2005), we present a short discussion of the methodology that underpins the catastrophic health expenditure literature. The method revolves around four basic measures and an estimated parameter (Xu *et al.*, 2003). The four measures are total household consumption expenditure, total household food expenditure, total out-of-pocket health payments and household size. Actual household size is assumed to overstate household needs, and, therefore, household equivalence, underpinned by the scale parameter, is used instead. Total expenditure includes all monetary and in-kind consumption, including home-made products. Food expenditure covers all food expenditure, ignoring alcohol, tobacco and food away from home; however, it is necessary to include food production at home, such as garden produce. Out-of-pocket payments cover any health care expenditure, except for health insurance premiums or any expenses that are re-imbursed through a 3^{rd} party.

The starting point is total expenditure, from which we subtract either subsistence expenditure (if the household's food expenditure exceeds their subsistence level) or food expenditure (if not) to determine the household's capacity-to-pay. Subsistence expenditure is determined by a survey-dependent poverty line, determined from the middle 10% of household equivalent food expenditures. Intuitively, it is the amount of food expenditure that is needed for each equivalent household member. The poverty line incorporates the equivalence scale through division; it is a per household member equivalent. On the other hand, subsistence incorporates equivalence, through multiplication – it is the total food requirement, or number of equivalents in the household times the poverty line. In other words, equivalence for the poverty line and subsistence are opposing, but not offsetting, and the exact effect of scale changes is an empirical issue; see the Mathematical Detour for more discussion.

Given capacity-to-pay and out-of-pocket payments, the share of the capacity devoted to out-of-pocket payments is the ratio. Once the share of capacity-to-pay devoted to out-of-pocket expenditures has been calculated, whether or not the household has been seriously affected by these payments can be derived, although it is underscored by an arbitrary threshold. Since out-of-pocket expenditure is fairly low in South Africa (J. E. Ataguba *et al.*, 2014; Koch, 2015), our analysis will focus on thresholds of 0.05, 0.10 and 0.15.

Mathematical Detour

As outlined above, following Xu (2005), the equivalence scale has two opposing effects. The first is in the definition of the poverty line, which includes the household equivalent food expenditure (or food expenditure divided by equivalent household size). Thus, a reduction in the equivalence parameter, θ, leads to an increase in the poverty line. However, the equivalence scale is multiplied back into the poverty line to determine the substistence level.

Defining f as household food expenditure, we pull out the middle 10% of the f distribution and calculate a weighted average. We define an indicator, $\mathbb{I}(f_e^{45} < f_{e,i} < f_e^{55})$, which is true (and therefore equal to one) if household i's equivalent food expenditure, $f_{e,i}$, lies between the 45^{th} and 55^{th} percentile of all equivalent food expenditure in the sample, where $f_e = f/n^{\theta}$, where n is the number of household members. The sample weighted average of equivalized food expenditure within this percentile range is referred to as the poverty line, ℓ. In (1), Ω_i refers to the household survey weight; the necessary percentiles of the food distribution were also determined after weighting.

$$\ell = \frac{\sum_{i:\mathbb{I}=1} \Omega_i \, f_i / n_i^{\theta}}{\sum_{i:\mathbb{I}=1} \Omega_i} \qquad (1)$$

Recall that the equivalence scale is multiplied back into this poverty line to determine the subsistence level for any household j:

$$\begin{aligned} s_j &= n_j^{\theta} \frac{\sum_{i:\mathbb{I}=1} \Omega_i \, f_i / n_i^{\theta}}{\sum_{i:\mathbb{I}=1} \Omega_i} \\ &= \frac{\sum_{i:\mathbb{I}=1} \Omega_i \, f_i \left(\frac{n_j}{n_i}\right)^{\theta}}{\sum_{i:\mathbb{I}=1} \Omega_i} \end{aligned} \qquad (2)$$

The derivative of (2) with respect to θ is not a common derivative, since the term of interest is an exponent, although it can be determined; see (3).

$$\frac{\partial s_j}{\partial \theta} = \frac{\sum_{i:\mathbb{I}=1} \Omega_i \, f_i \left(\frac{n_j}{n_i}\right)^{\theta} ln\left(\frac{n_j}{n_i}\right)}{\sum_{i:\mathbb{I}=1} \Omega_i} \qquad (3)$$

Intuitively, an increase in θ increases the subsistence level for relatively larger households and decreases it for relatively smaller households, since the sign depends on $\ln n_j - \ln n_i$. Furthermore, the effect is larger, in absolute value, when the poverty line is larger. Since household sizes differ, a change in the scale parameter will increase subsistence for some households, but reduce it for others. Thus, the overall picture of subsistence, capacity-to-pay, and, therefore, catastrophic payments is unlikely to change extensively. However, there will be differences for individual households, and they will depend on the size of the household relative to the size of the average household.

Estimating the Equivalence Scale Parameter

Xu *et al.* (2003) estimated a linear model covering a wide range of countries, and included country fixed effects to estimate the equivalance scale. Since we are working with only one country, we drop the fixed effects and regress the natural log of total food expenditures f against the natural log of household size n.

$$\ln f = \delta_0 + \theta_0 \ln n + \epsilon \qquad (4)$$

In the initial formulation, Xu *et al.* (2003) did not include household expenditure, and, since larger households tend to spend more, in total and on food, its exclusion potentially overstates the effect of household size. Therefore, we also allow for household expenditure x in the regression.

$$\ln f = \delta_1 + \theta_1 \ln n + \alpha_1 \ln x + \epsilon \qquad (5)$$

Thus, we estimate (4) without $\ln x$ and (5) with $\ln x$ to see if the initial estimate remains a reasonable approximation. For comparison, we also estimate an Engel-type equivalence scale underpinned by equivalence-scale-exactness, or base-independence (Blackorby and Donaldson, 1993; Blundell and Lewbel, 1991; and Donaldson and Pendakur, 2003; Lewbel, 1989; Pendakur, 1999). Intuitively, base-independence requires the equivalence scale to remain independent of expenditure. Defining w_f as the household budget devoted to food, x as before and z as household demographic information, while the superscript r connotes the reference household, a base-independent equivalence scale can be implicitly defined from the following relationship.

$$\begin{aligned} w_f(p, x, z) &= w_f(x^r, z^r) + \eta \\ &= w_f\left(\frac{x}{\Theta(z)}, z^r\right) + \eta \end{aligned} \qquad (6)$$

The model in (6) is highly nonlinear. Thus, one is left to estimate it using semiparametric methods, as in Pendakur (1999) or Yatchew *et al.* (2003). For our analysis, we follow the latter, rewriting (6) as a partially linear index model, where the function g is not known, and $X = \ln x - \theta_2 \ln n$.

$$w_f(x,z) = g(X) + \eta n + \varepsilon \qquad (7)$$

However, (7) is not a pure partially linear model, because X contains an additional parameter to be estimated, so it is also a linear index model. Therefore, we undertake a grid search over θ_2 and estimate η at each value of θ_2, following the double-residual method (Robinson, 1988). To undertake the grid search: (i) fix θ_2, (ii) nonparametrically estimate w_f against X, (iii) collect the residuals, (iv) nonparametrically estimate n against X, (v) collect the residuals, and (vi) regress the first set of residuals against the second set of residuals. We repeat this process over plausible values of θ_2 and choose the $\left(\hat{\theta}_2, \hat{\eta}\right)$ pair that minimizes the sum of squared errors. We use linear least-squares cross-validated local linear regression (Q. Li and Racine, 2004) for the nonparametric estimators, using the nonparametric package (Hayfield and Racine, 2008) for R (R Core Team, 2016). Additional details, including code and results, are available upon request from the authors.

Data

The data was taken from the 2010/11 South African IES (Statistics South Africa, 2013). The IES follows multi-stage stratified random sampling; thus, each response comes with a weight, defined at the level of the household, that can be used to create population relevant statistics.[4] The IES is designed to determine the consumption basket that underpins the Consumer Price Index. For that reason, the survey contains detailed information about household consumption, including food expenditure and out-of-pocket health

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[4] The household weight, $\Omega_i = (p_s \times p_h \times a)^{-1}$, where p_s refers to the probability that PSU "s" was chosen from the set of all PSUs demarcated by Statistics South Africa, p_h is the probability that household "h" was chosen from all of the households in the PSU, and a is the non-response adjustment. According to Statistics South Africa, the weights are benchmarked to the population in five year age groups and across population group using the SAS macro CALMAR. Those weights are used in the analysis; see (1).

expenditures. The survey also contains information about household members; we focus on their age, counting the total number of adults and the total number of children (aged 14 years or less). The Income and Expenditure Survey (IES) uses classification of individual consumption by purpose (COICOP) categories. Under COICOP, health expenditures lie in category 06, while food consumption primarily lies in category 01; See https://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5link

All expenditures on COICOP category 061 are coded as medical products, which includes medicines (with and without prescription), medical products (such as bandages and syringes) and therapeutic devices (including spectacles, hearing aids and braces). However, if medicines or bandages, for example, are given to outpatients or to inpatients, those expenses are not recorded in 061; instead, they would lie in 062 or 063. Expenditures on COICOP category 062 are coded as outpatient services, which is further separated into medical, dental and paramedical. It is expected that these services are delivered at home or in clinics. Expenditures in category 063 are coded as hospital services. Importantly, and somewhat confusingly, this last category often does not include surgeries, as many surgeries are managed as outpatient services. COICOP also includes categories 13.2 and 14.2, health expenditures made for households by either non-profit institutions (13.2) or by government (14.2); however, there are no such observations in the South African IES. Expenditures from 061-063 are aggregated to determine the total.

Descriptive statistics for the analysis data are presented in Table 1. The first column contains summary statistics for all households in the sample, which includes Asian households; as a subgroup, there are not enough Asian households to undertake a further separate analysis. In the remaining columns, data is reported by household population group. Only in 1994 was complete suffrage (for all citizens aged 18 and above) the law of the land. Preceding that election, individuals were discriminated against based only on population group. That discrimination advantaged whites, over coloureds over blacks, and, as can be seen in the table, there remains little sense of equality across population groups, yet. White households are the smallest, on average; they also spend the most on food, health care and all goods. Using Engel's criteria, white households spend the least on food as a share of their budget, and, therefore, white households have the highest level of welfare; Leibbrandt and Levinsohn (2011) reach fairly similar conclusions following more detailed methods.

Table 1 Descriptive Statistics of 2010 IES Data

	All HH	Black HH	Coloured HH	White HH
Household Size	3.78	3.83	3.85	2.67
Food Expenditure	971.02	849.03	1283.39	1671.03
Food Share	0.25	0.27	0.25	0.09
Food Share, Poorest 25%	0.35	0.35	0.38	0.14
Food Share, 25% - 50%	0.32	0.32	0.30	0.09
Food Share, 50%-75%	0.23	0.27	0.21	0.08
Food Share, Richest	0.11	0.15	0.12	0.06
Total HH Expenditure	6665.75	4633.02	7804.76	23158.33
OOP Expenditure	88.99	51.72	108.09	400.56

Total expenditure, food expenditure and out-of-pocket (OOP) health expenditure calculated according to Xu (2005) methodology using 2010 South African Income and Expenditure Survey (Statistics South Africa, 2013); however, the food share is the ratio of food expenditure to total household expenditure. All monetary values are presented in March 2011 South African Rand (ZAR6.77/$US1.00).

Results

Updated Scale Estimates

The updated scale estimates are presented in Table 2 for each of three models. They are labeled: "Xu *et al.* (2003) Update: $\hat{\theta}_0$", which follows (4); "Xu *et al.* (2003) Revised $\hat{\theta}_1$", which follows (5); and "Semiparametric Estimate: $\hat{\theta}_2$, which follows @(eq:indexmod1). In the original formulation (Xu, 2005; Xu *et al.*, 2003), the scale estimate was 0.56. As can be seen in the tabe, the updated, revised and semiparametric estimates – ranging from 0.30 to 0.52, depending on model and sample – are all lower. However, the results are not consistently rankable across population groups. For the update model, the highest scale is estimated for coloured households, and the update scale is 30% larger then the other estimates. On the other hand, the scale for white households for the update and semiparametric models are statistically indistinguishable. Although the scale parameter is not obviously the largest for white households, regardless of model, the estimate for black households is either the lowest, or not far from being the lowest. As expected, the results suggest that these households, the poorest, are forced to make their food budgets go farther than less poor households.

Table 2 Estimated Household Equivalence for Different Population Groups

Models	All HH	Black HH	Coloured HH	White HH
Xu et al. (2003) Update: $\hat{\theta}_0$	0.4504	0.4684	0.5214	0.5126
	(0.008)	(0.008)	(0.027)	(0.035)
R^2	0.12	0.15	0.12	0.10
Xu et al. (2003) Revised: $\hat{\theta}_1$	0.3266	0.3094	0.3625	0.3019
	(0.007)	(0.007)	(0.024)	(0.033)
R^2	0.39	0.37	0.37	0.25
Semiparametric Estimate: $\hat{\theta}_2$	0.4157	0.3664	0.3641	0.5121
	(0.004)	(0.004)	(0.045)	(0.126)
R^2	0.1590	0.2785	0.3831	0.2128

Xu *et al.* (2003) estimates of equivalence ($\hat{\theta}_0$) across population groups following (4). Xu *et al.* (2003) estimates of equivalence ($\hat{\theta}_1$) across population groups following (5). Semiparametric estimates of equivalence ($\hat{\theta}_2$) across population groups following (7), applying the double-residual method (Robinson, 1988); optimal bandwidths computed via least-squares cross validation (Q. Li and Racine, 2004). Standard errors in parentheses; all estimates are statistically significant at conventional levels.

In addition to reporting the estimates, we also report the coefficient of determination for each model. Although they are not directly comparable across models, we see that the update model is rather poorer in explaining food consumption than the semiparametric model is in explaining the household's food share. Including household consumption, which yields the revised estimate $\hat{\theta}_1$, suggests that household consumption is a relevant determinant of food expenditure. The semiparametric model also incorporates household consumption, at least indirectly. Thus, the results from either of the last two sets of estimates in Table 2 are to be preferred. Although the semiparametric estimates are more appropriate, in terms of economic theory, their estimation comes at the cost of extensive computation time, and, as we will see below, the equivalence scale has a limited effect on the incidence of catastrophic payments, although not on the joint distribution of catastrophe and household size. Therefore, applying a computationally simpler model will often be appropriate.

The Scale and its Effect

As discussed in the Mathematical Detour, the poverty line varies directly with the equivalence scale. Even though the subsistence level also depends upon the equivalence scale, and its effect can be signed, the overall effect of the scale is an empirical question. Therefore, we report estimates of the effect of the equivalence scale parameter on the poverty line, susbsistence level, capacity-to-pay and catastrophic payments (see Tables 3 and 4). Five scales are considered for the comparison, as are both black households, the most disadvantaged under apartheid, and white households, which were most advantaged.

The scales increase in value from left to right; the extremes, which are not estimated, are non-equivalence and per capita equivalence. Per capita corresponds to a unit scale parameter, and, therefore, assumes each individual in the household is identical in food needs. No equivalence assumes that household size makes no difference, e.g., the same amount of food expenditure is required to feed a household of one, two, three or even more. In between these extremes we include the "Semiparametric $\hat{\theta}_2$" and "Updated $\hat{\theta}_0$" results for the appropriate sample, taken from Table 2 Rows 1 and 3. Finally, we also include the initial estimate, denoted "Original $\hat{\theta}_0$", which is 0.56.

In each table, we use the entire data set to calculate the underlying poverty line, so it is the same in both tables.[5] The poverty line is calculated separately for each scale parameter, and is a single value for each subsample. However, there are many households in the sample, and each has its own subsistence, capacity-to-pay and catastrophic health care expenditure

[5] We have also estimated the poverty line separately across all samples, reaching the same general conclusion as we report here. Results available from the authors upon request.

result. For that reason, we report scale-specific averages of the subsistence level, capacity-to-pay and three catastrophic expenditure proportions; one proportion is based on a threshold of 5%, another on a threshold of 10% and the last is based on a threshold of 15%.

As expected, the poverty line falls with the scale parameter. For South Africa in 2010/11, it could be as low as R322.36 per capita or as high as R971.36, without equivalence. However, the effect of the scale parameter on subsistence is not monotonic. Although the poverty line varies by a factor of 3, the average subsistence level varies approximately 35%, top to bottom, for black households and about half that (16.4%) for white households. Average capacity-to-pay is hardly affected: 1.9% for black households and less than 0.5% for white households. Because average capacity-to-pay is effectively constant, despite the large differences in scale parameter and relatively large differences in average subsistence, the proportion of the population found to have suffered catastrophic health payments is also effectively constant.[6] Thus, there is little evidence to suggest that the choice of equivalence scale used in calculating catastrophic health payments following the Xu (2005) methodology matters to financial risk protection averages, at least in the case of South Africa in 2010/11.

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[6] We undertake the same analysis for all households, as well as for coloured households, reaching the same conclusions; results are available from the authors upon request. We also applied population-group specific poverty lines, finding similar results. Those results are also available upon request.

Table 3 Catastrophic Payments for Black Households

	No Equivalence	Semiparametric $\hat{\theta}_2$	Updated $\hat{\theta}_0$	Original $\hat{\theta}_0$	Per Capita
Estimated $\hat{\theta}$	0.0000	0.3664	0.4684	0.5600	1.0000
Standard Error	N/A	(0.004)	(0.008)	(0.002)	N/A
Poverty Line	971.36	583.69	561.16	497.20	322.36
Subsistence Level	971.36	906.06	995.17	997.49	1223.25
Capacity-to-Pay	3954.33	3955.13	3927.10	3927.98	3905.19
5% Threshold	9.632	9.576	9.692	9.667	9.662
10% Threshold	3.014	3.014	3.090	3.075	3.075
15% Threshold	1.173	1.183	1.203	1.203	1.183

Catastrophic payments and various components underpinning the catastrophic payments for black households. Column 1 assumes no equivalence, Column 2 assumed the scale parameter $\hat{\theta}_2$ from (7) is correct. Columns 3 and 4 assume the scale parameter $\hat{\theta}_0$ from (4) as updated or (Column 3) or the initial estimate (Column 4) from Xu *et al.* (2003). The final column assumes per capita equivalence.

Table 4 Catastrophic Payments for White Households

	No Equivalence	Semiparametric $\hat{\theta}_2$	Updated $\hat{\theta}_0$	Original $\hat{\theta}_0$	Per Capita
Estimated $\hat{\theta}$	0.0000	0.5121	0.5126	0.5600	1.0000
Standard Error	N/A	(0.126)	(0.035)	(0.002)	N/A
Poverty Line	971.36	583.69	561.16	497.20	322.36
Subsistence Level	971.36	934.09	898.48	834.44	859.69
Capacity-to-Pay	22250.17	22259.31	22282.67	22326.29	22321.31
5% Threshold	9.222	9.271	9.222	9.172	9.222
10% Threshold	3.223	3.123	3.123	3.123	2.975
15% Threshold	1.239	1.239	1.239	1.239	1.239

Catastrophic payments and various components underpinning the catastrophic payments for black households. Column 1 assumes no equivalence, Column 2 assumed the scale parameter $\hat{\theta}_2$ from (7) is correct. Columns 3 and 4 assume the scale parameter $\hat{\theta}_0$ from (4) as updated or (Column 3) or the initial estimate (Column 4) from Xu *et al.* (2003). The final column assumes per capita equivalence.

However, averages can be misleading. Therefore, we also examine the effect of the equivalence scale on the determinants of out-of-pocket payments (as a share of capacity-to-pay) and catasrophic health expenditure (using a 5% threshold). Those results, which include only a limited set of controls, such as household consumption, number of adults, number of children, provincial indicators and an urban indicator, are reported in Table 5. The first two columns focus on out-of-pocket payments, while the second set focuses on catastrophic health payments. Thus, the comparisons of interest are between Columns 1 and 2, as well as Columns 3 and 4. In Columns 1 and 3, we assume no equivalnce, while Columns 2 and 4 assume per capita equivalence.

Table 5 Determinants of the Share of Out-of-Pocket Payments and Catastrophic Health Care Payments (5% Threshold): The Effect of Equivalence Differences

	No Equiv OOP	Per Cap OOP	No Equiv CHE	Per Cap CHE
Intercept	0.2613	0.0948	2.9433	2.7343
	(0.105)*	(0.106)	(0.305)*	(0.304)*
Log HH Consumption	-0.6003	-0.5899	-0.7123	-0.7031
	(0.012)*	(0.012)*	(0.034)*	(0.034)*
Adults in HH	0.0537	0.0754	0.0545	0.0905
	(0.007)*	(0.007)*	(0.019)*	(0.018)*
Kids in HH	0.0307	0.0582	0.0416	0.0792
	(0.007)*	(0.007)*	(0.019)*	(0.019)*
Urban Locale	-0.0280	-0.0400	-0.1923	-0.1553
	(0.024)	(0.024)	(0.061)*	(0.061)*
Eastern Cape	-0.3018	-0.2951	-0.2608	-0.2989
	(0.057)*	(0.057)*	(0.184)	(0.183)
Northern Cape	-0.4340	-0.4354	-0.7390	-0.7654
	(0.076)*	(0.076)*	(0.286)*	(0.285)*
Free State	0.3476	0.3560	1.2309	1.1778
	(0.056)*	(0.056)*	(0.173)*	(0.171)*
Kwa-Zulu Natal	0.0621	0.0634	0.5501	0.5485
	(0.055)	(0.055)	(0.175)*	(0.173)*

Northwest	-0.1281	-0.1251	-0.1314	-0.1469
	(0.058)*	(0.058)*	(0.186)	(0.184)
Gauteng	-0.0208	-0.0175	0.2937	0.2546
	(0.053)	(0.053)	(0.176)	(0.175)
Mpumalanga	0.2217	0.2263	0.7364	0.7608
	(0.056)*	(0.056)*	(0.177)*	(0.175)*
Limpopo	-0.4242	-0.4204	-0.5141	-0.5328
	(0.058)*	(0.058)*	(0.187)*	(0.186)*

Determinants of the share of capacity-to-pay devoted to out-of-pocket payments (ordinary least squares regression, where the dependent variable is the natural log of the share, including only those who record out-of-pocket payment) along with the determinants of catastrophic health care expenditures (logistic regression based on 5% threshold, but includes all households). Results further separated by the scale parameter used to determine household equivalence, focusing on the extremes: $\hat{\theta} = 0$ (non-equivalence) and $\hat{\theta} = 1$ (per capita equivalence), to see if it matters to the determinants. Data for the analysis is limited to black households.

By definition, the equivalence scale is meant to account for the size of the household; thus, its value could affect conclusions related to household size variables in the determinants analysis. In our results, the number of adults and the number of children are more important determinants of out-of-pocket payment shares and catastrophic health expenditures, when the equvalence scale is larger; thus, the number of children and adults in the households has become a less important determinant of these two outcomes, given the reduction in the scale parameter we have found. Furthermore, the results suggest that catastrophic health care expenditure conclusions are manipulable through the choice of equivalence scale. For that reason, we recommend that researchers present their determinants analysis across a range of potential equivalence values, such as $\theta = \{0,0.5,1\}$.

Discussion

Our results suggest that household equivalence has changed. Xu *et al.* (2003), which included 1993 data from South Africa, estimated a scale parameter of 0.56. Our results suggest this could be overstated by as much as 46%. Given 17 years between that data and our data, as well as the significant changes to South Africa's legal and political landscape during that time, the changes are not too surprising. According to Wittenberg and Collison (2008) and Leibbrandt and Levinsohn (2011), households are, on average, one person smaller in 2008 than they were in 1992/93. Similarly, government has increased support for children, as well as the poorest, which has been good for the children, and reduced burdens within the household (DSD *et al.*, 2012; Duflo, 2003; Eyal and Woolard, 2013; Heinrich *et al.*, 2017). Increased transfer payments from government to families are likely to increase total consumption, as well as food consumption; however, even though there is evidence that such transfers reduce within-family remittances (Jensen, 2004), they also increase the size of the family, or at least the extended family, of recipients (Bertrand *et al.*, 2003). Even though households are smaller on average, the poorest, who are more likely to be dependent on social grants, are bigger, and, as our estimates imply, poorer households are spreading their food budgets thinly, leading to smaller equivalence scale estimates.

Table 6 The Effect of Equivalence on the Distribution of Catastrophic Payments at 5% and 10% Thresholds

	No Equiv 5%	Per Cap 5%	No Equiv 10%	Per Cap 10%
Equivalence Scale	0.000	1.000	0.000	1.000
One HH Member	1.828	1.612	0.647	0.544
Two HH Members	1.767	1.659	0.483	0.447
Three HH Members	1.474	1.469	0.508	0.508
Four HH Members	1.469	1.515	0.472	0.508
Five HH Members	1.099	1.171	0.303	0.344
Six HH Members	0.642	0.693	0.185	0.200
Seven HH Members	0.478	0.555	0.134	0.164
Eight HH Members	0.380	0.395	0.092	0.134
Nine HH Members	0.241	0.288	0.087	0.098
10+ HH Members	0.231	0.282	0.056	0.082

The proportion of households, given the size of the household, found to have faced catastrophic health care payments, assuming either no equivalence or per capita equivalence. Results further separated by the payment threshold used to define catastrophe, either 5% or 10%. Data for the analysis is limited to black households.

Despite the decrease in equivalence scales over this period, adjusting the estimates of catastrophic health payments to account for these scale changes has little impact on average catastrophic health expenditure in South Africa. Mathematically, the effect was not expected to be extensive, and we are able to verify that different sized househols are affected differently; see Table 6, which presents the distribution of catastrophic payments by household size for each of the extreme scale parameters, per capita and non-equivalence.

As expected, there is a tilt in the distribution comparison (across scale values) at the mean of household size. Table 1 describes the average household in South Africa to contain just fewer than 4 people, while equation (3) defines the scale parameter effect to switch sign at the average of household size. In other words, for households with fewer than 4 people, the larger scale results in less catastrophe, although it increases catastrophe for larger households. Thus, the estimated decrease in the scale parameter in South Africa, has had the opposite effect: catastrophe has been lessened for smaller households and has increased for larger households.

Concluding Remarks

This research has examined the effect of equivalence scale on the various components (especially, the poverty line, subsistence level and capacity-to-pay, as well as the resulting catastrophic health care payments distribution) of the World Health Organization's methodology for measuring financial risk protection in health care. The research: (i) applied the initial estimate from Xu *et al.* (2003) that determines equivalence within the WHO's method Xu (2005); (ii) updated the estimate following the regression structure outlined by Xu *et al.* (2003); (iii) revised it by also incorporating total household consumption; and (iv) developed a base-independent equivalence scale estimated via semiparametric methods (Yatchew *et al.*, 2003). The estimates were founded upon the 2010/11 South African IES (Statistics South Africa, 2013) for all households, as well as for three population subgroups. During Apartheid in South Africa, individuals were discriminated against according to race, and this policy was being slowly dismantled in

1993. Since the South African data included in Xu *et al.* (2003) was from 1993, it was expected that household behaviour, as measured by equivalence scales, would differ substantially from the initial estimate.

Our results support this expectation. Updated, revised and semiparametric equivalence scales were statistically significantly lower for all households, black households and coloured households, although not for white households. In some cases, the reduction was as much as 46%, in terms of the actual equivalence scale parameter. Given the large differences in equivalence scales, this research further examined the impact on the estimated poverty line, subsistence level, capacity-to-pay and catastrophic health care payments. Although the estimated poverty line increased by as much as 17%, the effect on the average subsistence level, capacity-to-pay and catastrophic payments was unimportant. Although not important for the average, the scale does affect conclusions regarding catastroph and household size. Thus, when applying the WHO method, we recommend considering alternative equivalence scales to see whether or not their values matter to the conclusions, especially those relating to the catastrophic health care payment distribution across households. Our analysis suggests that it is unlikely to lead to extensive differences, and, if differences are uncovered, estimating updated equivalence scale parameters, as done here, is a fairly innocuous task.

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Ethical Considerations: This research makes use of secondary data, and received ethical approval from the faculty and university in which the principal author is appointed.

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