

Greb, Friederike; Klasen, Stephan; Pasaribu, Syamsul Hidayat; Wiesenfarth, Manuel

Working Paper

Dollar a Day Re-Revisited

Discussion Papers, No. 91

Provided in Cooperation with:

Courant Research Centre 'Poverty, Equity and Growth in Developing and Transition Countries', University of Göttingen

Suggested Citation: Greb, Friederike; Klasen, Stephan; Pasaribu, Syamsul Hidayat; Wiesenfarth, Manuel (2011) : Dollar a Day Re-Revisited, Discussion Papers, No. 91, Georg-August-Universität Göttingen, Courant Research Centre - Poverty, Equity and Growth (CRC-PEG), Göttingen

This Version is available at:

<http://hdl.handle.net/10419/90455>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Courant Research Centre

‘Poverty, Equity and Growth in Developing and Transition Countries: Statistical Methods and Empirical Analysis’

Georg-August-Universität Göttingen
(founded in 1737)



Discussion Papers

No. 91

Dollar a Day Re-Revisited

**Friederike Greb, Stephan Klasen,
Syamsul Hidayat Pasaribu, Manuel Wiesenfarth**

August 2011

Wilhelm-Weber-Str. 2 · 37073 Goettingen · Germany
Phone: +49-(0)551-3914066 · Fax: +49-(0)551-3914059

Email: crc-peg@uni-goettingen.de Web: <http://www.uni-goettingen.de/crc-peg>

Dollar a Day Re-Revisited

Friederike Greb, Stephan Klasen, Syamsul Hidayat Pasaribu, and Manuel
Wiesenfarth¹

Courant Research Center 'Poverty, equity, and growth in developing and transition
countries'

University of Göttingen

Abstract:

Recently, the World Bank re-estimated the international poverty line used for global poverty measurement and the first Millennium Development Goal based on an updated country sample of national poverty lines and new results for PPP exchange rates. This generated the new international poverty line of \$1.25 per capita per day in 2005PPP\$. In this paper we show, using the same data, that the best statistical estimation of the relationship between mean consumption and national poverty lines generates an international poverty line that is substantially higher than \$1.25 a day.

¹ We would like to thank Martin Ravallion and Prem Sangraula for sharing the data set with us. Comments from participants of the Courant Center Conference in Göttingen (July 2011) and a workshop in Göttingen are gratefully acknowledged.

1. Introduction

In 2008, the World Bank presented its results from a major revision of the global absolute income poverty estimates, commonly known as the \$-a-day poverty numbers. These numbers measure the number, headcount ratio, and poverty gap of people in the developing world who fall below an international poverty line. This international poverty line had been created as the average of the national poverty lines of a sample of poor countries (with the lines expressed in PPP\$, see Ravallion, Datt, and van de Walle, 1991; Chen and Ravallion, 2001). The argument supporting this averaging has been that for a large range of low income countries, the observed national poverty lines are empirically rather similar, while for richer economies the poverty lines appear to rise with mean incomes (see Figure 1a). Since their inception in 1990, they have since become one of the central targets of the Millennium Development Goals.

As described in detail in Chen and Ravallion (2010), these revisions drastically changed the view on the level and distribution of global poverty in the world. In particular, the headcount rate of poverty in 2005 was now estimated at 25%, while prior to the revision, the number for the same year had been estimated (by the same authors) to be 17%. The difference implies that some 400 million more people (1.37 billion instead of 930 million) were now declared to be absolutely poor, compared to before. The level adjustments were particularly substantial in East Asia, followed by South Asia and Sub Saharan Africa, while they were much smaller elsewhere. The time trends in poverty between 1981 and 2005 were reported to be much more similar to before. Both are nicely summarized in the title of Chen and Ravallion (2010): 'The developing world is much poorer than we thought, but no less successful in the fight against poverty.'

The drastic revisions have generated considerable debates and commentary with several authors questioning aspects of the revisions (e.g. Deaton, 2010, Ward, 2009; Klasen, 2009; Reddy, 2008, Heston 2008) and this paper contributes to one aspect of this debate. This debate is complicated by the fact that the revision undertaken by the World Bank in 2008 included not one but two major changes. The first was to base the entire poverty analysis, including the international poverty line, on the new purchasing power parity estimates that had been produced in the 2005 round of the International Comparison of Prices Project (ICP2005), thereby discarding the previously used 1993 ICP. The 2005ICP suggested that many developing countries, including particularly China, but also India and some African countries were much poorer than previously thought, related to the higher price levels identified in the ICP. The second major change was that the new international poverty line was re-created using the same procedure but a different country sample that had previously been used. In particular, the poverty line switched from \$1.08 per capita per day at 1993PPPs to \$1.25 per capita per day at 2005 PPP.² While many surmised that the changes in levels and regional distribution of poverty were largely driven by the changes in the ICP, Deaton (2010) argued that this is unlikely to be the case. In particular, if the ICP simply made the average PPP-adjusted poverty line of the poor countries that make up the international poverty line lower than before (due to higher prices observed in these countries in the ICP2005), then this should not have any impact on measured poverty rates in the developing world. One way to test this assumption is to simply use the old sample of countries that made up the old international poverty

² This is discussed in detail in Ravallion, Chen, and Sangraula (2009) as well as Chen and Ravallion (2010)

line (\$1.08) and calculate the new poverty line. Using the median of the 10 countries included in the \$1.08 poverty line (Bangladesh, China, India, Indonesia, Nepal, Pakistan, Tanzania, Thailand, Tunisia, and Zambia, see Chen and Ravallion, 2001)³, the updated poverty line at 2005ICP would be \$1.05 per capita per day (or \$32.04 per month). Note that this apparent decline from \$1.08 to \$1.05 in the value of the poverty line despite international inflation in the intervening years⁴, precisely reflects the fact that the ICP2005 finds price levels to be much higher in poor countries (on average and relative to rich countries) than the 1993ICP. At the \$1.05 a day poverty line, the povcal database calculates that the number of poor people in 2005 would be 979 million, only slightly higher than the 931 million found using the old \$1.08 poverty line and the 1993ICP.⁵ Thus indeed it appears to be the case that the change in the ICP has a minor impact on the global number of poor people, while the switch in the sample to generate the new poverty line (i.e. essentially from \$1.05 to \$1.25) accounts for the bulk of the change to be explained.⁶ As a result, the question whether the new international poverty line is properly derived is the key question to examine.

Deaton (2010) already expressed a range of criticisms and suggested some ad hoc adjustments which we will discuss below. We will take a different route here though. We basically examine whether the newly derived international poverty line is properly specified when the most suitable econometric and statistical methods are applied to the issue. As shown in the next section, this essentially boils down to the question how best to estimate a regression line between (the log of) per capita consumption and the national poverty line (expressed in 2005PPP\$), allowing for a range of low-income economies where this relationship is flat, and an ascending portion covering richer economies where this relationship has a positive slope, given the shape of a piece-wise linear curve (see Figure 1a).

We first find that there are some problems with the way the methods proposed in Ravallion, Chen, and Sangraula (henceforth referred to as RCS) (2009) are actually applied in their estimation. In particular, they estimate a model that is not consistent with Figure 1a and thereby force a non-linear relationship on the data that is actually not warranted. Addressing this and other issues and additionally supplementing the analysis using straight-forward parametric and advanced non-parametric techniques, we find that the analyses based on these methods to derive the poverty line converge on a significantly *higher* poverty line, ranging from \$1.33 to \$1.53. We also find that there is a great deal of uncertainty surrounding these estimates, in fact substantially larger than suggested by RCS (2009).

The paper is organized as follows. The next section briefly discusses the way the international poverty line is derived, reviews Deaton's (2010) critiques and presents the basic framework for the analysis. The following section presents the methods used in the estimation, section 4 presents the results and section 5 concludes.

³ To create the median, we take the average of the two middle observations: Indonesia (\$32.63 a month) and Bangladesh (\$31.46 a month)

⁴ In fact, as calculated by Chen and Ravallion (2010), had one simply inflated the \$1.08 poverty line using the US CPI, the international poverty line in 2005 would be \$1.45.

⁵ See <http://go.worldbank.org/NT2A1XUWPO> accessed on March 23, 2011

⁶ This confirms the claim by Deaton (2010) who arrived at his conclusion using a different approach. Of course, the changes in the ICP will have larger impacts on the regional distribution of poverty to the extent the changes in the PPP exchange rates differ between and within regions which they did to some extent. See Deaton (2010).

2. Deriving the International Poverty Line

It is important to preface this section by emphasizing that we do not attempt to somehow generate some consistency between the old and the new poverty line.⁷ We thereby accept the (plausible) arguments advanced by Ravallion, Chen, and Sangraula (2009) that the data base used to generate the old international poverty line was dated, unrepresentative, too small, and with insufficient official status. Indeed, they show that the older database included only 22 observations, largely from the 1980s, while the new data base includes 74 observations from 1988-2005; the latter also appear to originate from more official sources while quite a few of the older ones were based on academic studies where it was unclear to what extent these poverty lines were officially accepted. A consequence of accepting this line of argument is that the 'revisions' prepared by the World Bank in 2008 are not so much 'revisions' and certainly cannot be considered an 'update': more properly, they are a completely new analysis starting essentially from scratch: a new poverty line is derived using a new sample of countries and new ICP data. The only link to previous estimates is that they are roughly based on the same empirical approach (see below); and the second link is that once the international poverty line has been derived for the benchmark year (now 2005, before 1993) and translated into local currency in that year, both approaches use *national* CPIs to inflate and deflate the poverty line backwards and forward in time and then use the household surveys of the respective years and the deflated poverty line to count the poor. As a result, it is, of course, not surprising that the trends in poverty have not changed a great deal. They have only changed to the extent that the location of the poverty line also affects the pace of poverty reduction. Since the density of people around the poverty line will differ depending on the location of the poverty line, this will affect poverty reduction, but the effect is empirically not substantial.⁸

Once it is accepted that one is essentially redoing the entire analysis from scratch, trying to find consistency with the previous estimate is no longer the pertinent question. The key question is whether the methods to do it now from scratch are the best available and the results robust to methodological choices. This is what we focus on here.

The empirical starting point for the analysis is Figure 1a which shows the log of per capita consumption from the national accounts and the national poverty lines, expressed in 2005PPP\$. These data are identical to the ones used by Ravallion, Chen, and Sangraula (2009). As can be seen, there clearly appears to be a range of low levels of per capita consumption where the relationship is flat, while the relationship turns clearly positive at higher levels of per capita consumption. Since the first derivation of the international poverty line, the essence of the international poverty line has been to take the average

⁷ For reasons explained, for example, in Reddy and Pogge (2008), it is not possible to generate inter-temporally consistent PPP-adjusted estimates of incomes or poverty. Each ICP produces PPP exchange rates valid for the benchmark year. Linking them with previous years using old ICP rounds (as was done using the Penn World Tables) or national inflation rates (as done in the World Bank poverty work) has different conceptual advantages and disadvantages. We also do not want to contribute here to the debate whether using the ICP rounds to derive an international poverty line and then calculate global absolute poverty numbers is conceptually a good idea. See Klasen (2009) for a discussion of these issues and possible alternatives.

⁸ See Bourguignon, (2003) and Klasen and Misselhorn (2007) for a precise statement on this under the assumption of lognormal income distributions.

of the flat portion of the curve,⁹ the central question is where the flat portion ends and the rising portion begins. In other words, what is the relevant reference group over which to calculate the average? Ravallion, Chen, and Sangraula (2009) end up with a reference group of the poorest 15 countries which then delivers a mean \$1.25 (and a median \$1.27) international poverty line. They use two approaches to get there. The first is to estimate the following parametric regression equation

$$Z_i = Z^*I_i + f(C_i)(1 - I_i) + \varepsilon_i$$

where Z^* is the mean poverty line of the reference group (countries with $C_i \leq C^*$) and also known as the estimated international poverty line, I_i takes the value one if i is a member of the reference group and zero otherwise.

Figure 1a. Threshold model for log(consumption).

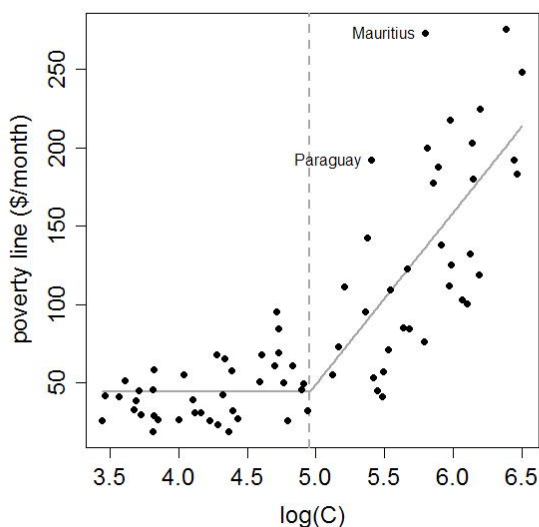
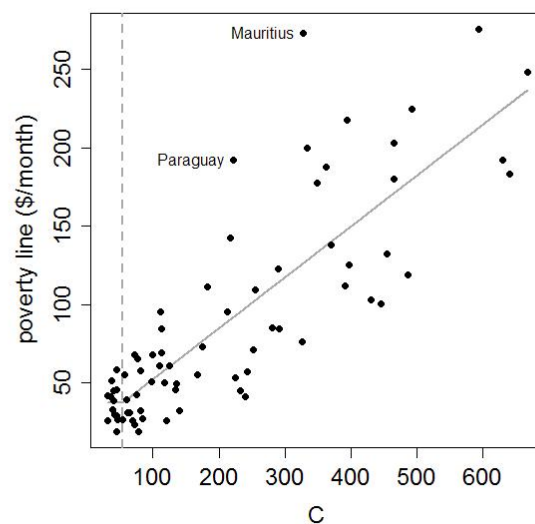


Figure 1b. Threshold model for consumption.



They then check whether the estimated curve is (roughly) continuous and whether the reference group is consistent so that the estimated per-capita consumption at the poverty line is below the maximum per capita consumption of the reference group and find this to be the case.

They concede, however, that their approach is statistically not valid as it treats “the regressor I as data since I is a function of C^* , which depends on the parameters.” (RCS 2009: 175). To remedy this, they estimate a constrained piece-wise linear threshold model based on Hansen (2000) where they constrain the model to have a slope of 0 in the lower linear segment and that there must not be any discontinuity at the kink. Using this approach, the estimate for Z^* is quite close (\$1.23).

⁹ In Chen and Ravallion (2001) using the old 1993ICP, the median of the countries along the flat portion was used. In Ravallion, Chen, and Sangraula (2009), the mean is used (although the median is also mentioned and does not differ much). To keep with the more recent approach, we will stick to the mean.

In his critique of the new global poverty numbers, Deaton (2010) is largely concerned with trying to establish some consistency between the old and the new numbers. He carefully investigates to what extent the change could be due to changes in the ICP and estimates that this might have boosted number by some 100 million poor people. The rest is due to the re-estimation of the poverty line using the new sample. Here Deaton criticizes that several populous fast-growing countries including China, India, Indonesia, and Bangladesh are no longer part of the new reference group. As some of them, notably India and China, have rather low poverty lines, their removal from the reference groups contributed to increasing the global poverty line and, paradoxically, leading to higher measures poverty using this global line, in India and China. He then proposes that a better procedure would be to calculate the international poverty line using all 74 observations, but weighed by the number of poor people in each country. This would, of course, mean that the international poverty line thus derived would be heavily driven by the poverty lines of the population giants India and China and many other data points would be largely irrelevant. This would then generate a poverty line of \$0.92 in 2005PPP\$ and a global poverty count of 874 million, actually lower than the last count using the old \$1.08 line of 931 million.

As we are not treating RCS as an 'update' (as Deaton implicitly does), we are less concerned about the consistency between the estimates (although it is of course interesting to understand what drives the differences). As to the weighting of the poverty lines, while one may give higher weight to poverty numbers that have been derived with greater technical competence or have been based on a great deal of public discussion (as has been the case in India), it appears implausible to assume that the credibility or standard of the poverty line is proportional to the poor people in the country. Also, this poverty line would then be influenced by countries in the ascending portion of the line which appears not right as in these countries apparently absolute poverty considerations have given way to more relative views of poverty and it appears unclear why these countries should influence the global absolute poverty line.¹⁰

Thus our approach is to more narrowly focus on the way whether the proposed two estimation methods discussed above are indeed the best to estimate the international poverty line. To this we now turn.

The first point of note is that both models actually estimated by RCS (2009) do not actually use the relationship in Figure 1a where the national poverty lines are plotted against respective *log* of per capita consumption. Instead both regressions use the just per capita consumption (not the log thereof) as the regressor. They thus try to estimate the relationship in Figure 1b. But the piece-wise linear relationship that drives the whole motivation for the international poverty line is actually not there in Figure 1b. This is apparent from visual inspection but can be formally tested. Using the Hansen model and assuming either homoscedasticity or heteroscedasticity, the test statistic (p-value) of the null hypothesis of no threshold (i.e. no kink) is 0.15 and 0.73, respectively. In both cases, one cannot reject the claim of a simply linear relationship between per capita consumption and the poverty line. In contrast, the respective p-value for the log-linear relationship in Figure 1a are 0.0002 and 0.005, respectively, clearly rejecting no threshold and confirming that the approach to estimate a piece-wise linear threshold model is justified.

¹⁰ On a closely related issue, see Ravallion and Chen (2010).

3. Identifying the Most Appropriate Reference Group

We now present several approaches to estimate the international poverty line based on different approaches to generating a reference group. In principle, we will follow two approaches. The first is to simply determine at which point the flat portion of the curve in Figure 2 experiences a slope that is significantly different from 0. We will investigate this question using parametric and non-parametric approaches. As soon as the curve has a significant positive slope, we can be sure that the optimal size of the reference group has (just) been exceeded, i.e. there must be a country (or countries) included where the poverty line depends on per capita mean income and no longer seems to be appropriate for inclusion for an absolute poverty line. That is, the reference group should include all countries where the relationship between the log of per capita consumption and the poverty line did not exhibit a positive relationship. In the simplest form, we simply run a linear parametric regression of increasing reference group sizes to determine where the slope begins to turn positive. Apart from the possibly problematic parametric assumption, one may object that the finding of the significant positive slope will depend on the number of prior observations where the slope was flat; the longer the flat portion, the more observations on the rising portion are needed to generate a significantly positive slope, clearly an undesirable feature of this approach.¹¹

To address this issue, we will also use a nonparametric approach to estimating the point where the slope turns significantly positive.

More precisely we now consider the model

$$Z_i = s(\ln C_i) + \varepsilon_i \quad (2)$$

where $s(\cdot)$ is a smooth function of unknown functional form. We use penalized splines to estimate this function (see Ruppert et al. (2003)). Thereby, the curve of interest is approximated by some spline basis based on a generous number of knots and overfitting is avoided by penalization with an integrated squared derivative of the spline function. We used cubic B-splines with penalty on the integrated squared second derivative of the spline function in order to get a twice differentiable curve. To obtain the estimated curve, we employ the mixed models representation of penalized splines due to the following advantages. First, this allows us to automatically estimate the smoothing parameter controlling the “wiggleness” of the curve from the corresponding restricted likelihood simultaneously with the remaining parameters. Secondly, heteroscedastic data can be easily handled with in this framework. Finally, this allows us to use a recent approach to construct simultaneous confidence bands which were shown to perform well even under such small sample sizes (see Krivobokova et al. ,2010, and Wiesenfarth et al., 2010)¹².

¹¹ Alternatively, if the slope is throughout slightly positive, simply adding observations will lead to a significantly positive slope eventually regardless of whether there is a true threshold.

¹² Due to lack of easily available simultaneous confidence bands that cover the entire true function with some pre-specified probability, usually pointwise confidence intervals are given. However, these bands correspond to the curve estimates at specific values of a covariate and do not assess the whole function. In particular, pointwise confidence intervals - in contrast to simultaneous confidence bands - do not allow statements about the statistical significance of certain features in a regression curve. In general, simultaneous confidence bands are wider than the pointwise ones.

In order to identify the point where the slope of the curve turns statistically significant, we estimate the first derivative $s'(\cdot)$ of the curve. Then, the slope is significant when the simultaneous confidence band around the first derivative does not enclose the zero line.

This nonparametric estimation is more appropriate as it can identify much more clearly where the shape of the curve changes, irrespective of the previous length of the flat portion. At the same time, it may still be the case that the identification of a significant positive slope will depend on the number of observations at the threshold; more observations lead to a more precise estimate and therefore might lead to an earlier finding of a positive slope (and thus a smaller reference group implying typically a lower international poverty line).¹³ We will investigate this sample size issue below. The crucial advantage of the nonparametric strategy is that no prior assumption on the functional form of the regression line can influence the estimation of the poverty line (the linearity assumption is clearly questionable as seen from Figure 3a). Further, the possible presence of outliers can barely have an effect.

The second approach to this issue is to estimate a piecewise-linear threshold model to estimate the full relationship presented in Figure 1a. There is a simple approach chosen also by RCS (2009) which is to estimate equation 1 above. We will do that as well, except that we, as discussed above, will estimate the log-linear model. We will also consider the continuity and consistency issues that they considered as discussed above.

But since this approach treats the reference group as data rather than as a function of C^* which itself is a parameter, we will also estimate, as did RCS, the piecewise linear threshold model using the procedure of Hansen (2000). The difference is that we will, following our threshold tests reported on above, only estimate the log-linear version of the model which was the only one where a threshold was identified in the data. More precisely, we will estimate the model

$$Z_i = Z^*I_i + f(\ln C_i)(1 - I_i) + \varepsilon_i \quad (3)$$

where $f(\cdot)$ is assumed to be linear as in Eq. (1). What has become known as Hansen's method is plain least squares estimation for threshold regression models. In our case, this amounts to finding the threshold C^* as the argument minimizing the sum of squared errors

$$\sum_{i=0}^n [Z_i - Z^*I_i - f(\ln C_i)(1 - I_i)]^2,$$

where C^* enters through I_i , Z^* and f . We minimize this function over all linear f restricted to meet the consistency and continuity conditions imposed; the parameters specifying f are concentrated out beforehand.

¹³¹³ A smaller reference group does not necessarily generate a lower average poverty line; it depends on whether the marginal observation is above or below the average. But for most cases, it will have this implication.

4. Results

Table 1 shows the results of the linear estimation. It turns out that, depending on the significance level chosen, the reference group of 29 countries or 30 countries would be appropriate in the sense that the slope would be clearly insignificant. This would lead to an international poverty line of X and Y, significantly above the \$1.25 a day, particularly if the mean of the reference group is chosen where the poverty line ranges from \$1.31 (G29) to \$1.33 (G30).

Table 1 Estimated Log-Linear Regressions

Indep. Variables	Dep. Variable = Z				
	G15	G29	G30	G31	G32
LnC	3.763 (0.19)	9.359 (1.19)	11.947 (1.70)	19.321* (2.17)	23.471** (2.77)
_cons	23.927 (0.32)	2.151 (0.07)	-7.826 (-0.28)	-36.288 (-1.04)	-52.321 (-1.57)
N	15	29	30	31	32
F-statistics	0.035	1.405	2.879	4.725	7.683
R-squared	0.003	0.048	0.083	0.166	0.228
Mean of Z	37.983	39.791	40.492	42.270	43.596
Median of Z	38.510	38.510	39.100	39.690	40.365

Note: t-statistics in parentheses based on robust standard errors and * p<0.05, ** p<0.01, *** p<0.001.

The nonparametric estimation results using simultaneous confidence bands are shown in Figure 3. As heteroscedasticity clearly is an issue here (see panel b), the simultaneous confidence bands need to be adjusted to take account of this. The first derivative of the nonparametrically estimated curve suggests that the slope turns significantly positive around a log of per capita expenditure of 4.42 (or \$83.01); this would generate a reference group of the 26 poorest countries and deliver a mean poverty line of about \$1.27 (95% confidence interval [\$1.09; \$1.46]). It is surprising that the line is very close to the \$1.25 found by RCS. This clearly suggests that the reference group of just the 15 poorest countries excludes a considerable flat portion of the curve in Figure 1a. In order to appreciate the great uncertainty inherent in these estimates, one can examine the predicted poverty line at the cut-off point of per capita expenditures of \$83.01, which would be an upper bound of the international poverty line as it is based on the point estimate where the slope has just turned significantly positive (instead of using the average of the flat portion). The point estimate is \$1.53 with confidence interval (as given by the simultaneous confidence band around the nonparametric fit) ranging from \$1.04 to \$2.03. So the nonparametric approach to identifying the flat portion of the curve suggests an international poverty line between \$1.27 and \$1.53, but with substantial uncertainty associated with these estimates.

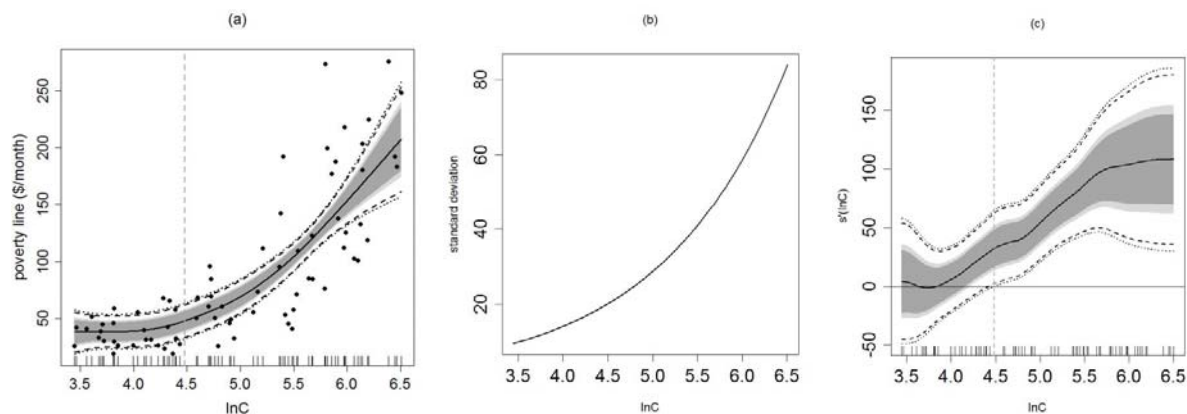


Figure 3: Nonparametric estimation of the log-linear relationship. Panel a shows the curve with the simultaneous confidence bands, panel b by the standard deviation of residuals (suggesting heteroscedasticity) and panel c the first derivative of panel a.

The piece-wise linear estimation of the log-linear curve is shown in Table 2. The choice of just 15 for the reference group of countries (as used by RCS (2009)) appears to be too low for several reasons. First, the fit of the regression is lower than when 29 or 30 countries are included in the reference sample. Second, if we check for consistency we find that at the estimated poverty line, the estimated log consumption is $\widehat{\ln C}^* = 4.43$. For the reference group of 15 countries, the cut-off $\ln C^* = 4.04$ (\$56.90). Thus while the reference group is technically consistent, a much larger reference group (comprising an additional 11 countries) would still be consistent as well. The consistency check for the reference group of 30 countries remains consistent. For 30 countries included in the reference group, we have estimated $\widehat{\ln C}^* = 4.72$. This is close to the actual value of $\ln C^* = 4.70$ (\$109.85) for those 30 countries. Third and closely related to the consistency issue, using the 15 countries as the reference group clearly creates a problem of a discontinuous piece-wise linear estimation as shown in Figure 4. In contrast, the choice of 30 countries as reference group does not suffer from these defects. As shown in Table 2 and Figure 4, it has a higher explanatory power and fulfills consistency and continuity properties. As a result, the estimated international poverty line would be about \$1.33 a day.

Table 2 Estimated International Poverty Lines (IPL) of Various Reference Groups

Indep. Variables	Dep. Variable = Z		
	G15	G29	G30
I	37.983*** (12.55)	39.791*** (14.64)	40.492*** (14.89)
1-I	-288.914*** (-8.28)	-380.743*** (-6.41)	-389.714*** (-6.22)
LnC(1-I)	73.792*** (10.24)	89.613*** (8.14)	91.311*** (7.92)
N	74	74	74
F-statistics	158.988	167.992	169.549
R-squared	0.878	0.884	0.884
Estimated IPL (Z^*) in \$ a day	1.25	1.30	1.33

Note: t-statistics in parentheses based on robust standard errors and * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

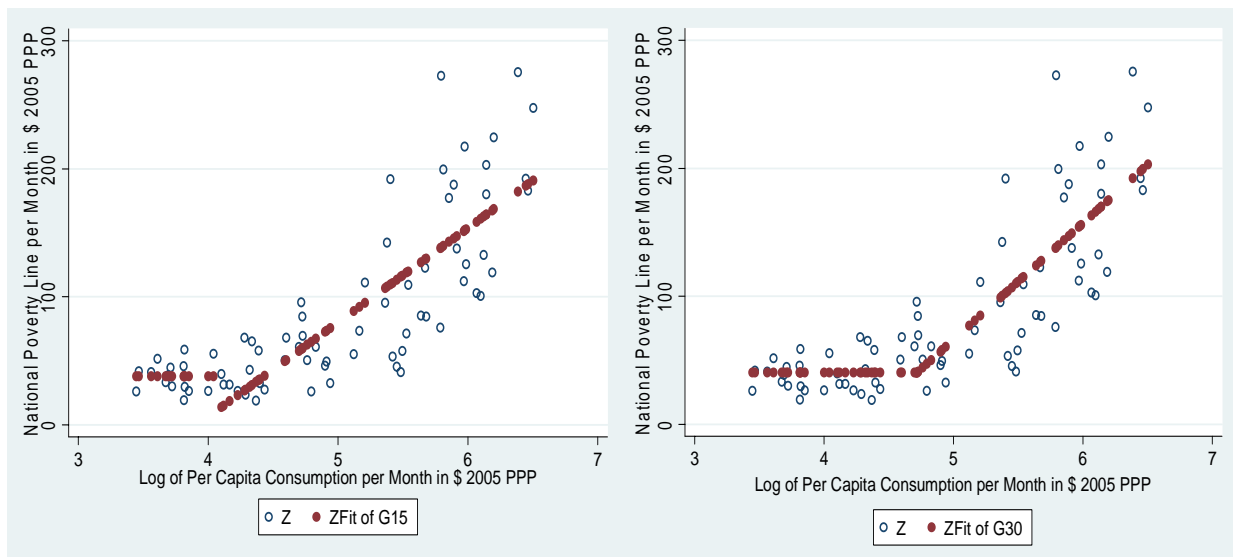


Figure 4 Continuity of piecewise function for G15 (left) and G30 (right)

Lastly, we consider the constrained threshold model following procedures by Hansen (2000), arguably the econometrically best way to approach the issue.¹⁴ The results are shown in Table 3. When estimating the log-linear model, the endogenously determined threshold is found to be at a level of $\ln C$ of 4.96, or a monthly per capita expenditure of \$142.6. Left of the threshold there are 39 observations (now including also India and China), and the estimated international poverty line stands at \$1.45.

¹⁴ Continuity and consistency problems cannot arise here as they are parts of the constraints for the estimation.

Asymptotic confidence intervals for the threshold translate into a global poverty line between \$1.10 and \$1.72 a day at 90% confidence level.¹⁵ Thus the possibly best approach to generating an international poverty line generates the largest reference group of 39 countries and a line that is substantially above the one found by Ravallion, Chen, and Sagraula (2010).¹⁶

Table 3. Estimation results for threshold model (2).

	\hat{c}^*	$\ln \hat{c}^*$	ref. group size	est. global poverty line	90 % confidence interval
complete set of 74 observations	142.38	4.96	39	\$1.45 a day	[\$1.10,\$1.72]
without Mauritius and Paraguay	161.77	5.09	39	\$1.45 a day	[\$1.27,\$1.86]

5. Some robustness checks

Some robustness checks

Our results so far indicate that all methods we propose to estimate this log-linear relationship between per capita expenditures and the national poverty lines (expressed in 2005PPP\$) generate a higher poverty line. Arguably the best approach generates a poverty line of \$1.45. We now do a range of robustness checks to assess the sensitivity of our findings.

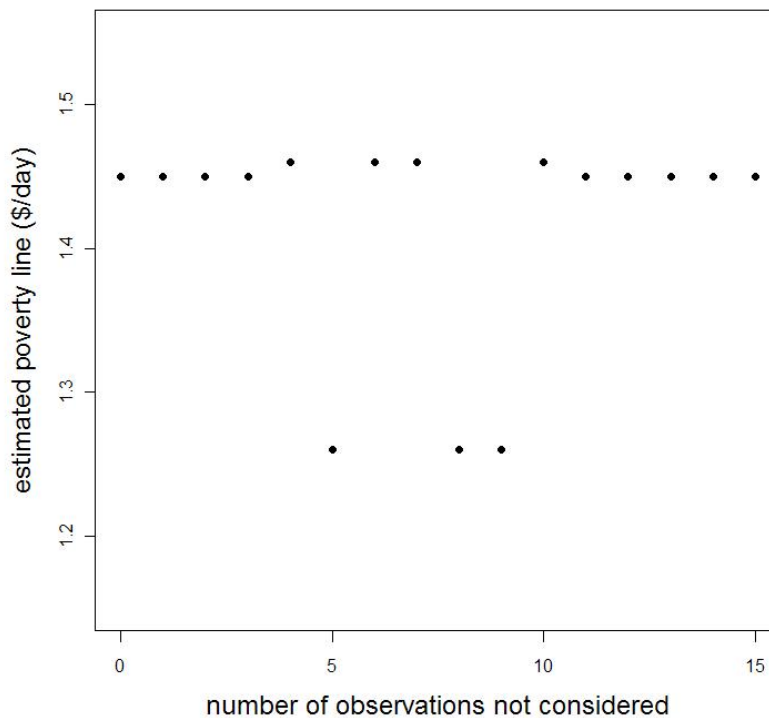
Regarding the first approach to estimating the international poverty line, i.e. determining when the flat portion in Figure 1a turns positive, sample size issues might play a role. It is the case that larger numbers of observations would generate more precise estimates and thus would lead to an earlier rejection of the flat slope. One (rather extreme) way to test this is to simply add a(?) each observation in the dataset a clone with the same values so that the sample size doubles without adding any new information to the dataset. In the linear estimation of the flat portion of the curve, the reference group where no significant positive slope is detected now reduces to 28 countries (at 10% significance level) or 29 countries (at 5% significance level), i.e. it is reduced by one observation each by doubling the sample size. Clearly, sample size is not a major driver of this relationship.

¹⁵ These confidence intervals have to be treated with upmost caution. Following RCS we base our strategy on Hansen (2000). However, the theory developed in Hansen (2000) is based on assumptions which do not hold for the constrained threshold model which we estimate here. Clearly, with respect to one of his assumptions, he notes that while it "might appear innocuous, it excludes the interesting special case of a continuous threshold model"; namely, it excludes our model. While this does not have consequences for estimation, our confidence intervals (computed as outlined in section 4.1 of Hansen, 2000, using kernel regression to estimate η^2 for the heteroscedasticity adjustment; and augmented to account for the variability of the poverty line implied) are based on an inappropriate asymptotic distribution. Furthermore, the value of asymptotic confidence intervals based on just 74 observations is questionable.

¹⁶ One should note that the threshold model estimation is sensitive to the functional form assumption on the right of the threshold. Choosing, for example, a quadratic function to the right of the threshold would deliver a somewhat lower poverty line. We follow RCS (2009) here as they assumed a linear function.

Similar results are found when we use the non-linear estimation approach. Doubling the observations leads to only a slightly lower level of per capita expenditures at which the simultaneous confidence bands suggest a significantly positive relationship (it falls from lnC of 4.42 to 4.34).

Figure 3. Estimates for reduced sets of observations.



When estimating the entire relationship directly, two issues might arise in a robustness check. The first is the sensitivity to outliers. As can be seen in the two figures, Mauritius and Paraguay are outliers in the sense that they have unusually high poverty lines, given their per capita expenditure levels. We therefore exclude these two countries in the constrained threshold model estimation. As shown in Table 3, the results do not change much at all. A second issue that might arise is that the fit of the entire curve as well as the identification of the threshold might be driven by observations that should arguably not drive the results. In particular, one might worry that the threshold and the associated international poverty line is heavily driven by country observations with high levels of per capita consumption and high poverty lines; those countries should arguably not have a large influence on the results. In a further robustness check, we progressively remove the observations with the highest levels of per capita expenditures. As shown in Figure 5, removing up to 15 observations does not generally change the identified threshold by much, in most cases it stays very close to \$1.45 a day.¹⁷

¹⁷ We explain the large effect of excluding 5, 8, or 9 observations with the fact that the threshold least squares estimator does not produce reliable results in certain settings, particularly in small samples. This view is encouraged when comparing least squares estimates with those obtained using a modified threshold estimator,

6. Conclusions

In this paper we revisit the derivation of the new international poverty line proposed by Ravallion, Chen, and Sangraula (2009). First we emphasize that it is critical to estimate the log-linear relationship as only that relationship actually shows a structural break which is at the heart of the issue of an absolute international poverty line. When doing so, all our estimates generate a significantly larger reference group for the estimation of the international poverty line. Our best estimate for the threshold model stands at \$1.45 per day. Of course, this would lead to a higher global poverty count than the new \$1.25 poverty line already generated. In fact, in 2005, we would now be looking at 1.74 billion absolutely poor in the world if we adopted that procedure for finding the new international poverty line.

References.

- Bourguignon, F. (2003), 'The growth elasticity of poverty reduction', in T. Eicher et al. (eds.) *Inequality and Growth* (Cambridge: MIT Press).
- Chen, S. and Ravallion, M. (2001), 'How Did the World's Poor Fare in the 1990s?' *Review of Income and Wealth* 47(3):283–300.
- Chen, S. and Ravallion, M. (2010), 'The developing world is much poorer than we thought, but no less successful in the fight against poverty'. *The Quarterly Journal of Economics* 125(4): 1577-1625.
- Deaton, A. (2010), 'Price indexes, inequality, and the measurement of world poverty'. *American Economic Review* 100(1): 5-34.
- Greb, F., Krivobokova, T., von Cramon-Taubadel, S., and Munk, A. (2011). Title etc will be added.
- Hansen, B. (1996). Inference when a Nuisance Parameter is not Identified under the Null Hypothesis. *Econometrica* 64: 413-430.
- Hansen, B.E. (2000), 'Sample Splitting and Threshold Estimation.' *Econometrica* 68(3): 575–603.
- Heston, A. (2008), 'The 2005 Global Report on Purchasing Power Parity Estimates: A preliminary review', *Economic and Political Weekly* 43 (11): 65-69.
- Klasen, S. (2009), 'Levels and Trends in Absolute Poverty in the World: What we know and what we don't'. Courant Research Centre PEG Discussion Papers No. 11, Göttingen University.
- Klasen, S. and Misselhorn, M. (2007), 'Determinants of the Growth Semi-Elasticity of Poverty Reduction', *Ibero-America Institute for Economic Research Working Paper* No. 176 (Göttingen: Ibero-America Institute).
- Krivobokova, T., Kneib, T. and Claeskens, G. (2010). Simultaneous confidence bands for penalized spline estimators. *Journal of the American Statistical Association*, 105(490): 852-863

which has proven to possess superior properties. The latter turn out to be more stable (see Greb, Krivobokova, von Cramon and Munk, 2011).

- Reddy, S. (2008), 'The World Bank's new poverty estimates: digging deeper into a hole'. Available at <http://www.socialanalysis.org>, [last accessed January 22, 2009].
- Reddy, S. and Pogge, T. (2009), 'How not to count the poor', in S. Anand, P.- Segal, and J.Stiglitz (eds.) *Debates on the Measurement of Global Poverty*. Oxford: Oxford University Press.
- Ravallion, M., Chen, S. and Sangraula, P. (2008), "Dollar a Day Revisited." Policy Research Working Paper 4620. World Bank, Washington, DC.
- Ravallion, M., Chen, S. and Sangraula, P. (2009), "Dollar a Day Revisited." *The World Bank Economic Review*, 23(2): 163–84.
- Ravallion, M., Datt, G. and van de Walle, D. (1991), "Quantifying Absolute Poverty in the Developing World." *Review of Income and Wealth* 37(4):345–61.
- Ruppert D., Wand, M.P. and Carroll, R.J. (2003). *Semiparametric regression*. Cambridge Univ Press.
- Ward, M. (2009). Identifying absolute global poverty in 2005: The Measurement Question. In Mack, E. M. Schramm, S. Klasen, and T. Pogge (eds.) *Absolute Poverty and Global Justice*. London: Ashgate , pp. 37-50.
- Wiesenfarth, M. , Krivobokova, T. and Klasen, S. (2010). Simultaneous Confidence Bands for Additive Models with Locally Adaptive Smoothed Components and Heteroscedastic Errors. Courant Research Centre: Poverty, Equity and Growth-Discussion Papers 50.