# Purchasing power parities and the Dollar-A-Day approach: An unstable relationship



**Author(s):**
Moatsos, Michail; Lazopoulos, Achillefs

**Publication date:**
2021-09

**Permanent link:**
https://doi.org/10.3929/ethz-b-000493941



**Originally published in:**
Economics Letters 206, https://doi.org/10.1016/j.econlet.2021.109974

Economics Letters 206 (2021) 109974

Contents lists available at ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

# Purchasing power parities and the Dollar-A-Day approach: An unstable relationship☆

Michail Moatsos [a,*], Achillefs Lazopoulos [b]

[a] Economic and Social History Group, Department of History and Art History, Utrecht University, Drift 6, 3512 BS, Utrecht, Netherlands
[b] Institute for Theoretical Physics, ETH Zurich, Otto-Stern-Weg 1, 8093, Zurich, Switzerland

ARTICLE INFO

*Article history:*
Received 25 May 2021
Received in revised form 21 June 2021
Accepted 22 June 2021
Available online 1 July 2021

*JEL classification:*
I32

*Keywords:*
Global poverty
PPP
Error
Dollar-A-Day
Inconsistency
Monte Carlo

ABSTRACT

We show that the Dollar-A-Day methodology in global poverty measurement provides inconsistent International Poverty Line (iPL) solutions when a complete set of consistency criteria in the iPL definition is used. This article illustrates that minor fluctuations in purchasing power parity exchange rates can yield inconsistent iPLs. We find a rate of inconsistency of 46.1% and we conclude that this is a worrisome attribute of the method.



## 1. Introduction

The Dollar-A-Day (DAD) global poverty measurement approach can be traced in its latest version in Ferreira et al. (2015). The main aspect of the method is the derivation of an international poverty line (iPL) that is applied to every country for any year, and is expressed in PPP international dollars.

Purchasing Power Parity (PPP) exchange rates are instrumental in the traditional global poverty measurement utilized by the World Bank and the United Nations for monitoring global poverty within the Millennium and the Sustainable Development Goals agenda. Their main function is to convert local currencies into an international common denomination that would express the purchasing capacity of each household independent of local currency denominations.

☆ We wish to thank an anonymous reviewer for the suggestions in improving this article, and Angus Deaton for providing us his estimates on PPP uncertainty. We also benefited greatly from discussions with Francois Bourguignon, Martin Ravallion, Francisco Ferreira, Christoph Lakner, Prem Sangraula, Auke Rijpma, and Jan Luiten van Zanden. All analysis has been conducted with R open source statistical computing software (R Core Team, 2018). All remaining errors are ours alone.

* Corresponding author.
*E-mail addresses:* m.moatsos@uu.nl (M. Moatsos), lazopoulos@itp.phys.ethz.ch (A. Lazopoulos).

## 2. Materials and methods

Ravallion et al. (2009) (hereafter RCS) revised in 2005 PPP terms the definition of the iPL previously followed by Ravallion et al. (1991) and Chen and Ravallion (2001). Their estimation of the iPL included two steps: (i) selecting a reference group of countries, and (ii) taking the average of the national poverty lines from the countries in that reference group.

When Ferreira et al. (2015) adjusted the iPL to the 2011 PPP exchange rates they did not follow the method introduced by their colleagues at the World Bank in Ravallion et al. (2009). Instead they kept the same countries in the reference group of Ravallion et al. (2009), thereby making their iPL to depend both in 2005 and 2011 PPPs.

### 2.1. The Dollar-A-Day

To define the iPL Ravallion et al. (2009) use the following equation:

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

$Z_i$ is the poverty line of country $i$, $Z^*$ is the average of the reference group's National Poverty Lines (NPLs), $I_i$ takes the value of one when country $i$ belongs to the reference group and zero otherwise, and $f(C_i)$ is a function of consumption per capita per month $C_i$. The function $f(C_i)$ is fitted as a linear function of $C_i$ corresponding to non-reference group countries. The estimated

https://doi.org/10.1016/j.econlet.2021.109974

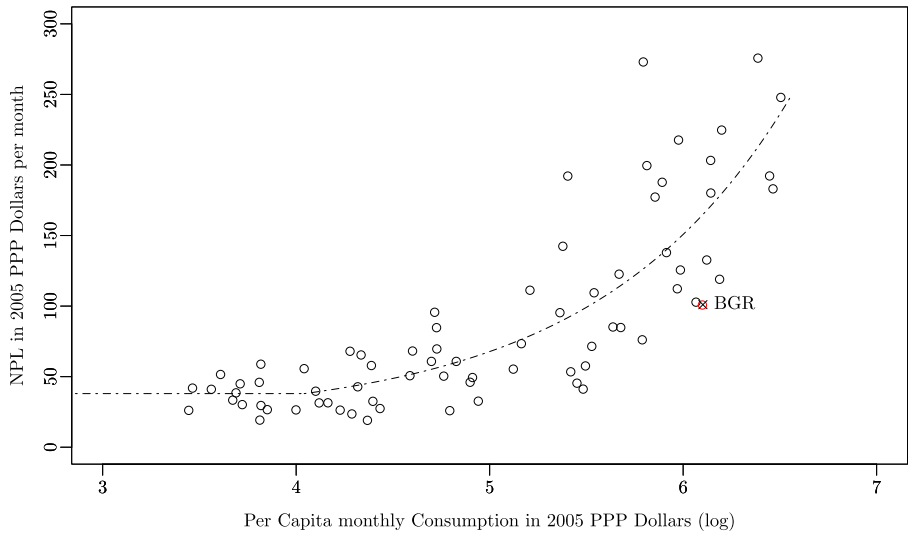


**Fig. 1.** The elbow fitting of the National Poverty Lines as a function of log consumption per capita for the 74 countries in the RCS data set, using the PovcalNet PPP exchange rates. PPP rates for Bulgaria (BGR) are specially marked (discussed in the results section).

**Table 1**
**Elbow fitting original.** Numerical results for the elbow fitting of the Ravallion et al. (2009) data set for the first 30 countries. All monetary values in 2011 PPP dollars per month, except iPL that is given in per day values. (b) and (c) correspond to the criteria (b) and (c) described in the text; 1 corresponds to fulfilling the criterion and 0 for not. See main text for the explanation of the criteria. See main text for the explanation of the criteria.

| | ISO3 | Cons. | $C^*$ | iPL | beta0 | beta1 | (b) | (c) | DAD |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MWI | 31.34 | | 26.110 | | | | | 0.86 |
| 2 | MLI | 31.96 | 39.311 | 34.000 | 21.403 | 0.320 | 1 | 0 | 1.12 |
| 3 | ETH | 35.22 | 47.387 | 36.347 | 21.128 | 0.321 | 1 | 0 | 1.19 |
| 4 | SLE | 36.94 | 60.853 | 40.145 | 20.500 | 0.323 | 1 | 0 | 1.32 |
| 5 | NER | 39.34 | 56.657 | 38.786 | 20.495 | 0.323 | 1 | 0 | 1.28 |
| 6 | UGA | 40.01 | 56.994 | 38.740 | 20.313 | 0.323 | 1 | 0 | 1.27 |
| 7 | GMB | 40.88 | 60.812 | 39.623 | 19.895 | 0.324 | 1 | 0 | 1.30 |
| 8 | RWA | 41.33 | 56.858 | 38.441 | 20.014 | 0.324 | 1 | 0 | 1.26 |
| 9 | GNB | 45.12 | 60.576 | 39.277 | 19.575 | 0.325 | 1 | 0 | 1.29 |
| 10 | TZA | 45.26 | 52.797 | 37.269 | 20.180 | 0.324 | 1 | 0 | 1.23 |
| 11 | TJK | 45.49 | 61.433 | 39.229 | 19.187 | 0.326 | 1 | 0 | 1.29 |
| 12 | MOZ | 45.52 | 58.454 | 38.422 | 19.381 | 0.326 | 1 | 0 | 1.26 |
| 13 | TCD | 47.04 | 54.711 | 37.512 | 19.742 | 0.325 | 1 | 0 | 1.23 |
| 14 | NPL | 54.55 | 50.939 | 36.721 | 20.240 | 0.324 | 0 | 1 | 1.21 |
| 15 | GHA | 56.90 | 56.935 | 37.983 | 19.448 | 0.326 | 1 | 1 | 1.25 |
| 16 | ZMB | 60.40 | 57.336 | 38.089 | 19.420 | 0.326 | 0 | 1 | 1.25 |
| 17 | NGA | 61.49 | 55.062 | 37.695 | 19.821 | 0.325 | 0 | 1 | 1.24 |
| 18 | BGD | 64.34 | 52.722 | 37.348 | 20.297 | 0.323 | 0 | 1 | 1.23 |
| 19 | BFA | 68.54 | 48.587 | 36.765 | 21.155 | 0.321 | 0 | 1 | 1.21 |
| 20 | COG | 72.13 | 56.908 | 38.327 | 19.861 | 0.324 | 0 | 1 | 1.26 |
| 21 | BEN | 72.82 | 51.683 | 37.624 | 20.999 | 0.322 | 0 | 1 | 1.24 |
| 22 | KHM | 75.06 | 52.037 | 37.859 | 21.138 | 0.321 | 0 | 1 | 1.24 |
| 23 | YEM | 76.37 | 59.018 | 39.055 | 19.914 | 0.324 | 0 | 1 | 1.28 |
| 24 | SEN | 78.92 | 51.825 | 38.222 | 21.630 | 0.320 | 0 | 1 | 1.26 |
| 25 | MNG | 80.55 | 56.201 | 39.008 | 20.918 | 0.322 | 0 | 1 | 1.28 |
| 26 | VNM | 81.18 | 52.599 | 38.758 | 21.961 | 0.319 | 0 | 1 | 1.27 |
| 27 | IND | 84.24 | 46.794 | 38.338 | 23.578 | 0.315 | 0 | 1 | 1.26 |
| 28 | PAK | 98.31 | 47.353 | 38.778 | 23.875 | 0.315 | 0 | 1 | 1.27 |
| 29 | MRT | 99.63 | 53.449 | 39.791 | 22.838 | 0.317 | 0 | 1 | 1.31 |
| 30 | KGZ | 109.85 | 56.361 | 40.492 | 22.582 | 0.318 | 0 | 1 | 1.33 |

version of Eq. (1), as it appears in RCS and shown in Fig. 1, is as follows[1]:

$$\begin{aligned} Z_i = 37.983 I_i \quad &+(19.388 \quad +0.326 C_i)(1-I_i) \quad +\hat{\varepsilon}_i \\ (12.55) \quad &(2.99) \quad (11.15) \\ R^2 = 0.890 \quad , \quad &n = 74. \end{aligned} \tag{2}$$

[1] T-ratios in parenthesis based on robust standard errors.

Ravallion et al. (2009) split the set of 74 countries in their data, in order to separate the absolute poverty from relative poverty components, and thus they fit an elbow function. In this setup, the critical issue is where the consumption per capita threshold is located (shown in Fig. 1) which would provide a consistent solution according to the following criteria: (a) the continuity criterion that requires $Z^* = f(C^*)$ at the threshold, and (b) the consistency criterion requiring $C_i < C^*$ for all countries $i$ in the reference group.

$f(C)$ and $Z^*$ are estimated directly from the data so they are used to determine the threshold level by actually enforcing the aforementioned continuity criterion (a). Table 1 shows the detailed results of this investigation at various threshold levels within the original (Ravallion et al., 2009) set of countries. Ravallion et al. (2009) find that \$60 is a consistent solution and includes 15 countries in the reference group.

Importantly, in the above discussion one consistency criterion is omitted, and must be added to the two above. It stems from the trivial observation that for a threshold to be consistent it should in addition hold that:

(c) for any country $j$ not in the reference group $C_j > C^*$.

Intuitively, the need for this criterion is similar to the need behind criterion (b), as criterion (c) is the complimentary of (b). Criterion (b) is required to assure that the fitted line in the non-reference group will not have a gradient that makes its fitted line intersect with the fitted horizontal line of the reference group below the $C^*$ consumption level (see also the–lognormal– Fig. 1 for an overview). Likewise, criterion (c) is required to guarantee that the intersection of these lines will not happen at a location above the consumption level of any country *not* belonging to the reference group. Only when taken together the three criteria above guarantee that the gradient of the second fitted line of the elbow is such that their intersection will happen within the consumption per capita area between reference and non-reference countries.

### 2.2. Microsimulations

Our approach for teasing out the frequency with which the solutions to the choice of threshold provided by the Ravallion

**Table 2**
**Elbow fitting amended.** Numerical results for the elbow fitting of the Ravallion et al. (2009) data set for the first 30 countries, with the slight modification of Bulgaria's (BGR) PPP rate (see text for details). All monetary values in 2011 PPP dollars per month, except iPL that is given in per day values. (b) and (c) correspond to the criteria (b) and (c) described in the text; 1 corresponds to fulfilling the criterion and 0 for not.

| | ISO3 | Cons. | $C^*$ | iPL | beta0 | beta1 | (b) | (c) | DAD |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MWI | 31.34 | | 26.110 | | | | | 0.86 |
| 2 | MLI | 31.96 | 39.283 | 34.000 | 21.416 | 0.320 | 1 | 0 | 1.12 |
| 3 | ETH | 35.22 | 47.360 | 36.347 | 21.141 | 0.321 | 1 | 0 | 1.19 |
| 4 | SLE | 36.94 | 60.830 | 40.145 | 20.514 | 0.323 | 1 | 0 | 1.32 |
| 5 | NER | 39.34 | 56.632 | 38.786 | 20.509 | 0.323 | 1 | 0 | 1.28 |
| 6 | UGA | 40.01 | 56.968 | 38.740 | 20.328 | 0.323 | 1 | 0 | 1.27 |
| 7 | GMB | 40.88 | 60.786 | 39.623 | 19.910 | 0.324 | 1 | 0 | 1.30 |
| 8 | RWA | 41.33 | 56.830 | 38.441 | 20.029 | 0.324 | 1 | 0 | 1.26 |
| 9 | GNB | 45.12 | 60.548 | 39.277 | 19.591 | 0.325 | 1 | 0 | 1.29 |
| 10 | TZA | 45.26 | 52.766 | 37.269 | 20.196 | 0.324 | 1 | 0 | 1.23 |
| 11 | TJK | 45.49 | 61.404 | 39.229 | 19.204 | 0.326 | 1 | 0 | 1.29 |
| 12 | MOZ | 45.52 | 58.422 | 38.422 | 19.398 | 0.326 | 1 | 0 | 1.26 |
| 13 | TCD | 47.04 | 54.676 | 37.512 | 19.759 | 0.325 | 1 | 0 | 1.23 |
| 14 | NPL | 54.55 | 50.901 | 36.721 | 20.258 | 0.323 | 0 | 1 | 1.21 |
| 15 | GHA | 56.90 | 56.899 | 37.983 | 19.466 | 0.325 | 0 | 1 | 1.25 |
| 16 | ZMB | 60.40 | 57.298 | 38.089 | 19.439 | 0.325 | 0 | 1 | 1.25 |
| 17 | NGA | 61.49 | 55.021 | 37.695 | 19.841 | 0.324 | 0 | 1 | 1.24 |
| 18 | BGD | 64.34 | 52.679 | 37.348 | 20.317 | 0.323 | 0 | 1 | 1.23 |
| 19 | BFA | 68.54 | 48.541 | 36.765 | 21.176 | 0.321 | 0 | 1 | 1.21 |
| 20 | COG | 72.13 | 56.863 | 38.327 | 19.883 | 0.324 | 0 | 1 | 1.26 |
| 21 | BEN | 72.82 | 51.634 | 37.624 | 21.021 | 0.322 | 0 | 1 | 1.24 |
| 22 | KHM | 75.06 | 51.986 | 37.859 | 21.161 | 0.321 | 0 | 1 | 1.24 |
| 23 | YEM | 76.37 | 58.967 | 39.055 | 19.938 | 0.324 | 0 | 1 | 1.28 |
| 24 | SEN | 78.92 | 51.769 | 38.222 | 21.654 | 0.320 | 0 | 1 | 1.26 |
| 25 | MNG | 80.55 | 56.144 | 39.008 | 20.944 | 0.322 | 0 | 1 | 1.28 |
| 26 | VNM | 81.18 | 52.538 | 38.758 | 21.988 | 0.319 | 0 | 1 | 1.27 |
| 27 | IND | 84.24 | 46.726 | 38.338 | 23.605 | 0.315 | 0 | 1 | 1.26 |
| 28 | PAK | 98.31 | 47.283 | 38.778 | 23.904 | 0.315 | 0 | 1 | 1.27 |
| 29 | MRT | 99.63 | 53.378 | 39.791 | 22.868 | 0.317 | 0 | 1 | 1.31 |
| 30 | KGZ | 109.85 | 56.288 | 40.492 | 22.613 | 0.318 | 0 | 1 | 1.33 |

et al. (2009) methodology turn out to be inconsistent uses a Monte-Carlo microsimulation (Bailer-Jones, 2017; Chib, 2001). The core idea in this approach is that the PPP exchange rates corresponding to the 74 NPLs used in Fig. 1 are being sampled following a log-normal distribution following Rao et al. (2010), as implemented in Moatsos and Lazopoulos (2021).[2]

### 2.3. Data

The PPP error terms that we use here are coming from Rao et al. (2015), which cover both 2005 and 2011 ICP rounds for 181 countries. The PPP error terms they provide relate to the consumption GDP component, and therefore is a better match with the concept of the household final consumption PPP compared to the error terms provided by the other sources which relate to GDP as a whole (Deaton and Dupriez, 2011; Deaton, 2012). In addition, on average they are less than half the estimates made by Deaton (2012), and have an average standard deviation of 5.7% for 2005. This makes our implementation a rather conservative one.[3]

## 3. Results

Fig. 1 shows the elbow fit using the PPP rates of PovcalNet, and provides identical conclusions as in RCS, suggesting a 1.9$-a-day as the result of a consistent reference group selection (shown in Table 1). It further considers the case of a small deviation from those PPP rates for one country (see supplementary material for details). In the case of Bulgaria's PPP rate, for example, it only takes a very modest 0.25% relative change to render the reference group results inconsistent (when the standard error for Bulgaria is estimated at around 3%).[4]

In our microsimulations the entire procedure of estimating the iPL is repeated 10,000 times and the PPPs for each repetition are drawn from 2005 PPP exchange rates using the log-normal error terms estimated by Rao et al. (2015). In 46.1% of the cases the consistency test fails. When we exclude criterion (c) from our microsimulations then only 1.8% of the cases fail to be consistent to criteria (a) and (b).

## 4. Discussion

Our results indicate that the solutions produced by the original criteria (a) and (b) are consistent at a very high rate of 98.2%. However, solutions that are only consistent according to criteria (a) and (b) cannot be deemed as overall consistent since in almost half the cases they will violate the sine-qua-non criterion (c) defined above, which is omitted in the original DAD procedure.

## 5. Conclusions

The Dollar-A-Day methodology for measuring global poverty is shown to be sensitive to very small fluctuations of the Purchasing Power Parity exchange rates, which are well within the error terms of the PPPs. We demonstrate this on the entire set of NPLs used in the derivation of the iPL by utilizing a complete set of criteria for consistency, contrary to the use of non-complete criteria in the original Dollar-A-Day method. The omission of criterion (c) in the original procedure by the World Bank researchers (Ravallion et al., 2009) appears to be critical. We conclude that the high rate of inconsistency in the Dollar-A-Day method is a worrying attribute for the method, particularly when it has been shown that the method as a whole (excluding its inconsistency problem) is remarkably prone to uncertainty (Moatsos and Lazopoulos, 2021).

## Appendix. Supplementary material

### A.1. Detailed discussion of consistency break down

The consistency breaks because of the $C^*$ moving from slightly above the consumption per capita in the most affluent country in the reference group (Ghana), to slightly below it. Thus violating the consistency criterion (b) which requires that $C_i < C^*$ for all countries in the reference group. If we were to simply remove Ghana from the reference group and recalculate the iPL with the 14 remaining NPLs we would face the same problem, as also in this case criterion (b) is violated. See row 14 in Table 2, where $C^*$ is 50.901 while consumption per month and per capita for the 14th country (Nepal) is 54.55, thus including Nepal in the reference group makes it inconsistent. We need to remove yet another country from the group (namely Nepal) to be consistent with criterion (b). However, in this case we will be violating consistency criterion (c), which requires that for any country $j$ not in the reference group $C_j > C^*$, since there is a country (Nepal) not in the reference group that has consumption per capita lower than the $C^*$. Observe for this matter row 13 in Table 2, where $C^*$ is 54.676 while consumption per month and per capita for Nepal is 54.55, thus requiring Nepal to be included in the reference group. As Table 2 shows, any threshold selection would fail to separate the reference from the non-reference group with this PPP draw, since there is no country at which both criteria (b) and (c) are met.

[2] All analysis has been conducted with R open source statistical computing software (R Core Team, 2018).

[3] Deaton (2012), for example, estimates for China and India give a relative standard error of 15%, a value similar to most other countries in his estimates.

[4] Appendix A.1 in supplementary material discusses the mechanics of the consistency break in detail.

## References

R Core Team, 2018. R: A Language and Environment for Statistical Computing.
Ferreira, F.H.G., Chen, S., Dabalen, A., Jolliffe, D., Narayan, A., Prydz, E.B., Revenga, A., Sangraula, P., Yoshida, N., 2015. A global count of the extreme poor in 2012: data issues, methodology and initial results. In: Policy Research Working Paper. The World Bank, Washington, DC, p. 7432.
Ravallion, M., Chen, S., Sangraula, P., 2009. Dollar a day revisited. World Bank Econ. Rev. 23 (2), 163–184.
Ravallion, M., Datt, G., van de Walle, D., 1991. Quantifying absolute poverty in the developing world. Rev. Income Wealth 37 (4), 345–361.
Chen, S., Ravallion, M., 2001. How did the world's poorest fare in the 1990s? Rev. Income Wealth 47 (3), 283–300.
Bailer-Jones, C.A.L., 2017. Practical Bayesian inference: A primer for physical scientists.
Chib, S., 2001. Chapter 57 - Markov chain Monte Carlo methods: Computation and inference. Handb. Econom. 5, 3569–3649.
Rao, D.S.P., Rambaldi, A., Doran, H., 2010. Extrapolation of purchasing power parities using multiple benchmarks and auxiliary information : A new approach. Rev. Income Wealth 56 (Special Issue 1).
Moatsos, M., Lazopoulos, A., 2021. Global poverty : A first estimation of its uncertainty. World Dev. Perspect. 22, 100315.
Rao, D.P., Rambaldi, A.N., Huynh, L.T., Doran, H.E., Ganegodage, K.R., 2015. UQ International Comparisons Database: UQICD Version 2.1.2.
Deaton, A., Dupriez, O., 2011. Spatial price differences within large countries.
Deaton, A.S., 2012. Calibrating measurement uncertainty in purchasing power parity exchange rates. In: Working Paper. Princeton University.