A consistent dataset for the net income distribution for 190 countries and aggregated to 32 geographical regions from 1958-2015

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Abstract

Data on income distributions within and across countries are becoming increasingly important to inform analysis of income inequality and to understand the distributional consequences of climate change. While datasets on income distribution collected from household surveys are available for multiple countries, these datasets often do not represent the same concept of inequality (or income concept) and therefore make comparisons across countries, over time and across datasets difficult. Here, we present a consistent dataset of income distributions across 190 countries from 1958 to 2015 measured in terms of net income. We complement the observed values in this dataset with values imputed from a summary measure of the income distribution, specifically the GINI coefficient. For the imputation, we use a recently developed principal components-based approach that shows an excellent fit to data on income distributions compared to other approaches. We also present another version of this dataset aggregated from the country level to 32 geographical regions. Our dataset is developed for the purpose of calibrating models such as Integrated human-Earth system models with detailed data on income distributions. This dataset will enable more robust analysis of income distribution at multiple scales.

1. Introduction

Data on income distributions are important to understand trends in global and regional income inequality. These data are also routinely used to train models that project income distributions into the future (Fujimori et al., 2020; Hallegatte & Rozenberg, 2017; Hughes et al., 2009; Hughes, 2019; Soergel et al., 2021; Van der Mensbrugghe, 2015). In the climate literature, long-term projections of within-country income distribution have been used to inform analyses of how the impacts of climate change may affect inequality and poverty (Hallegatte & Rozenberg, 2017; Jafino et al., 2020). Income distribution data are generally collected through national and local household surveys. The most prominent sources of national-level income distribution data are the datasets presented by the World Bank through the PovCal tool (Bank, 2015) and the income distribution datasets available from the Luxembourg Income Study (LIS) (Ravallion, 2015; Smeeding & Grodner, 2000). Both these datasets present useful time series of income distribution for income groups such as deciles, based on multiple household surveys.

While these datasets have been widely used, they are subject to certain limitations. The definition of income in these datasets is often not the same, making comparisons across countries and datasets difficult (Smeeding & Latner, 2015). For example, the PovCal dataset has mixed observations for net income and consumption for the same country in different years. Such inconsistencies can occur because the underlying surveys in different years might have been conducted to measure different ~~income concepts~~ concepts of inequality (hereafter referred to as income concepts) . The two income concepts that these data tend to use are:

i) ***Post tax income or disposable income or net income*** - This measure is defined as employee income plus income from firms (self-employment) plus income from rentals (excluding any payments), property income (these are generally capital gains and include dividends) plus current transfers received (these include insurance benefits, employer contributions) less transfers paid (taxes paid and employee contributions). This is the concept of income recommended by the Canberra group for the international comparison of incomes (Europe, 2011).

ii) ***Consumption*** - This measure is the sum of food consumption plus non-food consumption plus durable goods purchases (expenditure value minus cost of repairs) plus housing expenditures (rent, mortgage payments) less any payments made (taxes, loan payments, asset purchases, etc). This is the concept of income recommended by Deaton & Zaidi (2002) for welfare measurement.

Temporal and spatial coverage of the data are another issue. The LIS dataset provides consistent data on the net income distribution. However, these data are only available for 50 countries from 1980 to 2016. The PovCal dataset provides data for a considerably higher number of countries (165) compared to the LIS. However, the data are a combination of net income and consumption-based observations (net income distribution data for 73 countries and consumption distribution data for 118 countries).

Previous studies that have made use of these datasets for analysis or for modelling income distributions have treated these income concepts as interchangeable (Rao et al., 2019; Sauer et al., 2020). Moreover, for countries where no survey data on income distributions are available, studies have used simple methods such as using a summary measure of income distribution such as the GINI coefficient in combination with a parametric functional form such as a lognormal distribution to impute the within country or within-region income distribution (Fujimori et al., 2020; Rao et al., 2019; Shorrocks & Wan, 2008; Soergel et al., 2021).

There have been efforts to generate consistent datasets of the income distribution. However, these efforts have been limited to local or regional data. For example, Frank (2009) generated a consistent dataset of income distribution metrics for a single income concept for the fifty US states. That particular study builds on previous studies that have compiled data for the US states(Piketty & Saez, 2003). At the national level, there have been some efforts to produce standardized datasets of income inequality, but they have generally been limited to summary metrics of the income distribution such as the GINI coefficient (Babones & Alvarez-Rivadulla, 2007). Lanker and Milanovic (2013) developed a useful time series of income deciles across countries which is a combination of data from the LIS, PovCal and other sources. However, this dataset is still a combination of different income concepts and has a limited temporal time series (the dataset only extends to the year 2013).

In this study we present a consistent dataset on national income distributions that represents a single income concept namely, net income. This dataset contains a total 8522 data points of income deciles across 190 countries. This dataset is constructed by first choosing net income decile data observations from all available sources for all available countries (1191 observations). For countries that only have consumption distribution data, we impute the net income distribution using a regression-based approach (494 observations). For countries and years where no data on income distribution is available, we impute income deciles using the GINI coefficient combined with a principal component analysis (PCA) based method that provides a better fit to data than existing methods (6837 observations). This PCA-based method was recently developed as a non-parametric approach to projecting income distribution (Narayan et al., 2023). While this method was primarily used for generating estimates of future income distribution, the same was also validated against historical data (as described in sections below) and hence was selected as a valid method to perform imputations. We note that the PCA based imputation provides the maximum number of observations in the dataset.

One intended use of this dataset is to initialize income distribution variables in the Global Change Analysis Model (GCAM) (Calvin et al., 2019). GCAM is a global, integrated model of the energy, land, water, climate, and socioeconomic systems that produces projections for several economic, climatological and physical systems variables for 32 geopolitical regions. Hence, we also present income distributions for these 32 aggregated regions in addition to the 190 countries. We use an aggregation method that takes into account cross-country inequality within a region in addition to within-country inequality.

This dataset can be used to train projection models for income distribution across different scales and, given the consistent income concept represented, can also be used to understand trends within and across countries and regions. While these data are generated to enable modelling of the income distributions in GCAM, they can be used to train any model for projecting income distributions.

2. **Dataset construction**

We explain our approach for the dataset construction in detail in the sections below. To summarize, we used the following steps:

a. We first identified observations by country and year of net income deciles from all available datasets (LIS, PovCal, and individual research studies). In doing so, we prioritized the LIS dataset over all other datasets given its high data quality on the net income distribution. Our selection process is explained in **section 2.1 and 2.2** below.
b. For countries/years in which there were no net income data, but consumption data was available, the net income distribution was imputed from the consumption distribution using a regression-based approach. This is explained in **section 2.3**.
c. Where there were no net income or consumption data, but the GINI coefficient, a summary metric of the income distribution, i.e., was available, we imputed the net income distribution from the summary measure using a PCA-based approach. This is explained in **section 2.4**.

Note that point c. in the above yields the maximum number of data points in our final dataset. Table 1 below summarizes the coverage of our dataset-

Type of data	**country-year observations**
Original data on net income ***(Explained in section 2.2)***	1191
Imputed based on original data on consumption ***(Explained in section 2.3)***	394
Imputed from GINI coefficient (using PCA algorithm) ***(Explained in section 2.4)***	6837
Total	**8522**

Table 1: Summary of data points covered in our data set

2.1 Literature review and data selection from available household survey data

We first conducted a literature review to identify sources of national-level data on income distributions for as many countries as possible. There are three main datasets available, from the Luxembourg Income Study (LIS)(Ravallion, 2015; Smeeding & Grodner, 2000) the World Bank (whose data on income distributions are available through the PovCalNet tool) (Bank, 2015) and UNU WIDER (which compiles data from different sources including the LIS, PovCal and other research studies) (WIDER, 2008). Each dataset contains income distribution data for different income concepts such as net income and consumption, based on nationally representative surveys that may also represent sub-groups of the population (e.g., Urban vs Rural). These data are sometimes supplemented with data from research studies, and they use different equivalence scales to convert from household to per capita income. We first evaluated data availability for net income deciles based on these criteria (income concept, scale, temporal coverage, and spatial coverage).

In Table 2, we summarize these datasets differentiated by these criteria. Since the UNU WIDER dataset is a compilation of data sources (i.e., LIS, PovCal or others), we also identified the number of observations (country-year) in the UNU WIDER data derived from each source. **SI Table 1** of this document summarizes some of the other studies which were used in the collection of data for the UNU WIDER database.

We are primarily interested in decile-level income distributions derived from household surveys. Given our criteria for data selection, we limited our data collection to the datasets mentioned above. For example, we did not use the Standardized World Income Inequality Database (Solt, 2020) since it includes only the GINI coefficient and not a full distribution by income groups (such as deciles). Similarly, we did not use the World Inequality Database (Chancel et al 2021) since this dataset is not based on household survey data (This database uses a distributed national account methodology). However, as more detailed datasets become available, they can be included in our dataset.

Source	**Income concept**	**Scale of survey**	**Countries**	**Years (range)**	**Observations (n)**
Luxemburg income study	Net income	National	50	1980-2016	347
	Consumption	National	25	1980-2016	209
PovCalNet	Net Income	National	73	1981-2018	1644
		Urban/Rural	3	1981-2018	37
	Consumption	National	114	1981-2018	2341
		Urban/Rural	3	1983-2018	54
UNU WIDER	Net Income	National	163	1979-2017	1707 347 from LIS 533 from other sources 827 from PovCal
		Urban	22	1961-2018	315 51 from PovCal 264 from other sources
		Rural	20	1950-2017	215 3 from PovCal 212 from other sources

	Consumption	National	66	1973-2018	1030 116 from LIS 779 from PovCal 135 from other sources
		Urban	5	1975-2017	52 45 from PovCal 7 from research studies
		Rural	5	1975-2017	50 46 from PovCal 4 from research studies

Table 2: Summary of coverage by data source

We also evaluated access to microdata (i.e., underlying household-level data from household surveys) for each of these datasets, since detailed microdata allows us to validate and understand how the different income distributions for different income concepts were arrived at. Of all datasets evaluated, we found that the LIS database has the most access to microdata via the METIS tool (https://www.lisdatacenter.org/frontend).

The PovCal database maintained by the World Bank has the highest coverage geographically and temporally in terms of observations. PovCal uses the disposable income data from LIS for high- and middle-income countries and uses household survey data for consumption and disposable income for low-income countries. The scales of the surveys are mostly national other than India, China, and Indonesia where distribution data from separate rural and urban surveys are available. Mean and median values of the income concepts are available in 2011 USD PPP converted using country-specific conversion factors.

PovCal sometimes combines data of different types even within countries, e.g., for China, PovCal uses income data in early years up to 1990 and then switches to consumption data. Moreover, the micro-data for PovCal are not readily available.

UNU WIDER releases quality scores of individual datasets. It classifies the LIS database as “High quality”, due especially to the availability of metadata, and classifies the PovCal dataset as “Average quality”. Figure 1 below shows the income distributions by deciles for different countries for different income concepts from the UNU-WIDER dataset.

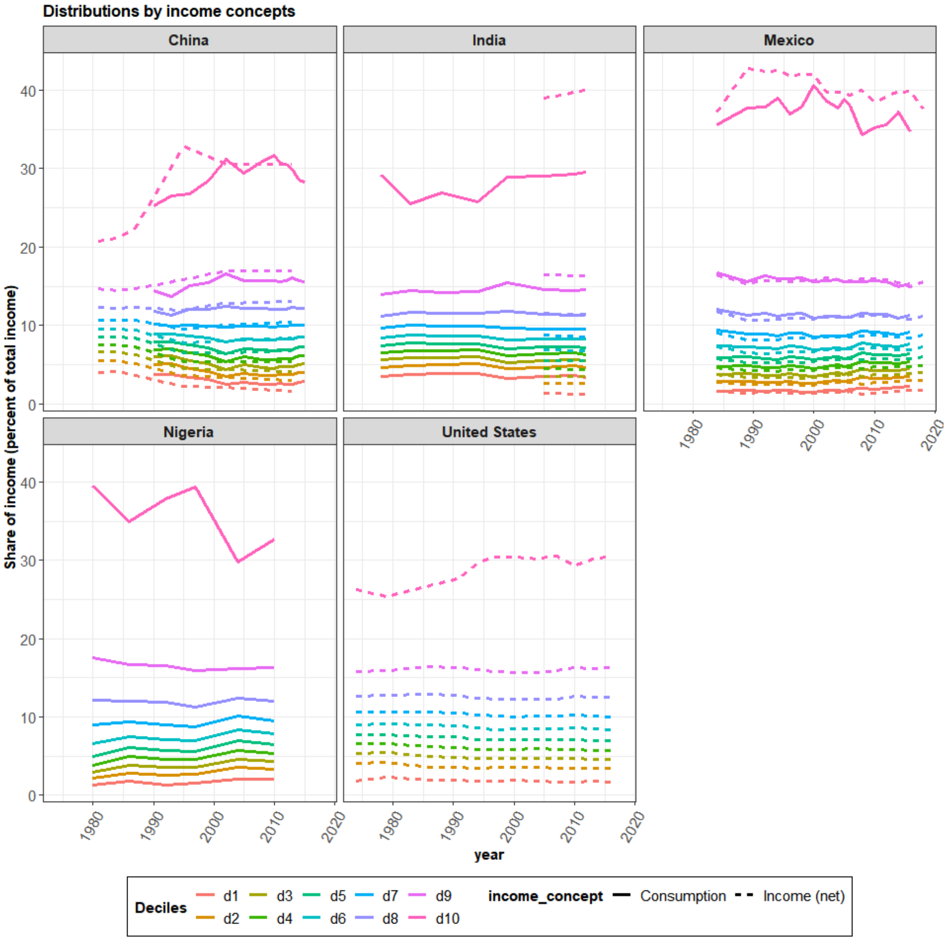

Figure 1: Income distributions across countries (facets) for different deciles (color) for different income concepts (line types) from the UNU WIDER dataset

2.2 Selection of income concept and scheme for selection of data points

We construct a dataset that represents solely net income based on the same per-capita equivalence scale. The per capita equivalence scale is calculated using total household income divided by the household size assuming equal sharing of income. Our process, summarized in Figure 2, improves upon other attempts to construct income distribution datasets from different sources (Rao & Min, 2018; Rao et al., 2019), since the previous studies used the income concept from different datasets interchangeably. We primarily select observations for net income deciles across countries from the LIS, given the high quality of data available from that dataset. We begin by compiling separate datasets of the income distribution for net income and consumption. In construction of both these datasets, we prioritize data points from the LIS. If no data were available from the LIS for a country-year, we selected an observation of net income or consumption from the PovCal database. Finally, if data were not available from that database, we rely on income distribution data from other research studies available from the UNU WIDER database. Note that when selecting values across multiple research studies we select values based on the rating assigned by the UNU WIDER database to the studies. All data are selected for the equivalence scale applied in the WIDER dataset, in which household income was converted to per capita units by dividing the household income by the household size assuming equal sharing of income. Note that when selecting data points, the WIDER dataset presents data in multiple equivalence scales. This enabled us to select data that represent a single equivalence scale.

Thus, at this stage, we compiled two different data sets, one that represents net income distribution across countries across time and another that represents consumption for the same countries. Now, we prioritize the selection of net income distribution values over consumption for each country-year.

Where data are only available for the consumption distribution, we convert the consumption data to net income data (as explained in section 2.3 below), using a regression approach to generate a harmonized dataset of net income deciles. Where necessary, we aggregated data sources across different survey scales (urban vs. rural) using a population-weighted average.

Figure 2 summarizes our data selection approach.

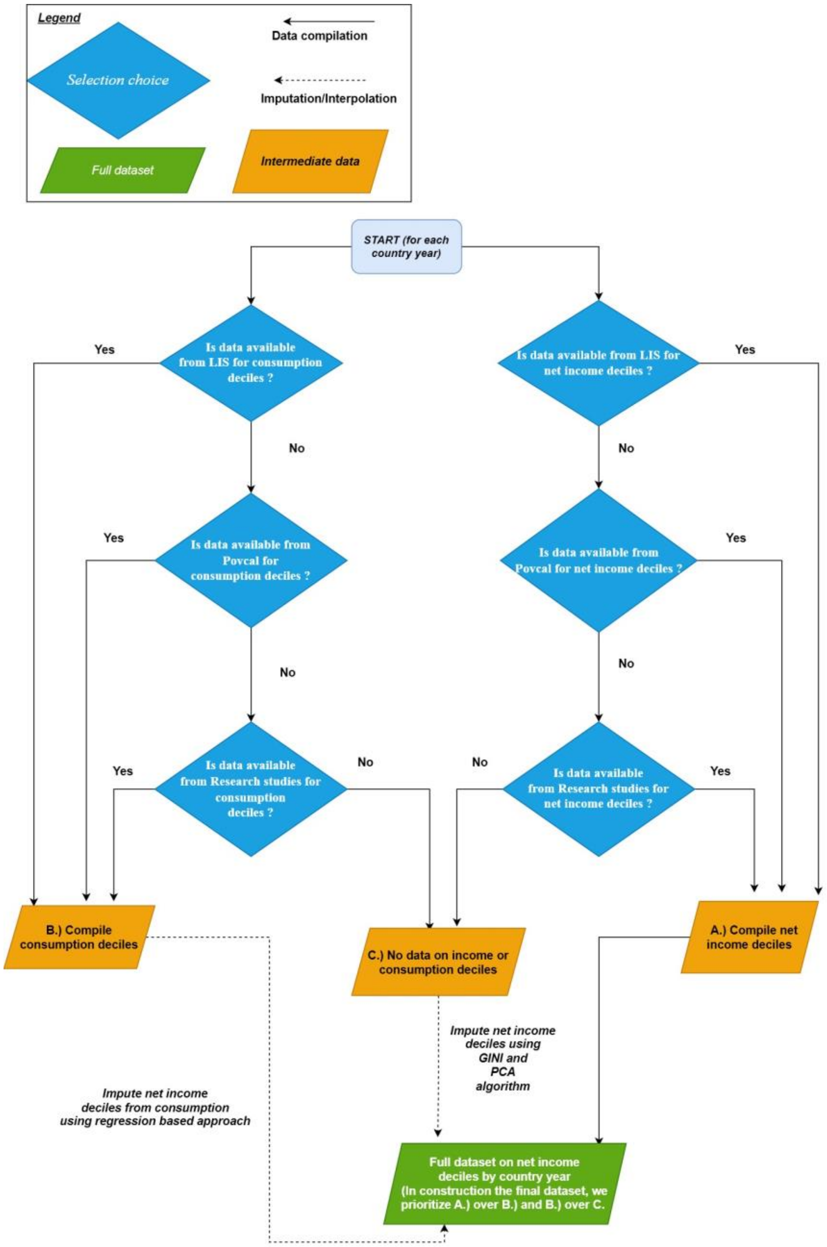
Legend
Selection choice
Data compilation
Imputation/Interpolation
Full dataset
Intermediate data
START (for each country year)
Yes
Is data available from LIS for consumption deciles ?
No
Is data available from LIS for net income deciles ?
Yes
No
Yes
Is data available from Povcal for consumption deciles ?
No
Is data available from Povcal for net income deciles ?
Yes
No
Yes
Is data available from Research studies for consumption deciles ?
No
No
Is data available from Research studies for net income deciles ?
Yes
B.) Compile consumption deciles
C.) No data on income or consumption deciles
A.) Compile net income deciles
Impute net income deciles using GINI and PCA algorithm
Impute net income deciles from consumption using regression based approach
Full dataset on net income deciles by country year (In construction the final dataset, we prioritize A.) over B.) and B.) over C.

Figure 2: Summary of data selection approach for each country, year observation

Based on the above, we evaluated data coverage for the 229 countries we are targeting. The geographical boundaries of the 32 GCAM regions are defined based on these 229 countries (countries with their corresponding regions are listed in **SI Table 2**). We identified observations after the selection above for four categories, namely countries where we have net income data for at least one year, countries where we had both net-income and consumption distribution data for at least one year (in case of these countries we selected the net income distribution value for deciles), countries where we had only consumption data, and countries where there were no data (these countries only had data on aggregate measures of inequality such as the GINI coefficient but no data on income deciles). Table 3 below summarizes the number of observations (country years) by category of data.

Data availability (for at least 1 year) by income concept	**Number of countries**	**Notes on use**
Net income only	33	Use net income share data.
Both net income and consumption	54	Use net income share data.
Consumption only	83	Imputed income shares to be calculated (See section 2.3)
No decile data available but GINI is available	14	Impute deciles based on GINI coefficient (See section 2.4)
No data available	39	Drop from data set (section 5)
Total	**229**	

Table 3: Summary of data availability by income concept.

2.3 Imputing net income shares using consumption shares

Using data for countries which had both income and consumption distribution observations for the same years (n=257, across 54 countries where each of which have data for ten deciles of consumption and the ten deciles of net income), we constructed linear regression equations based on a training dataset (n=148) for each decile to impute the net income shares using the consumption shares of the income distribution (Figure 3). The highest R squared value was observed for the fifth, sixth, seventh and tenth deciles d10 of 0.~~74~~ 78 and the lowest R squared value was observed for d9 of 0.~~37~~48. We calculate values for 9 deciles d1-d8 and d10 and the recalculate d9 as the residual. This is because d9’s regression equation was found to have the lowest R squared value amongst the 10 deciles. We have verified that all imputed decile values add up to 1.

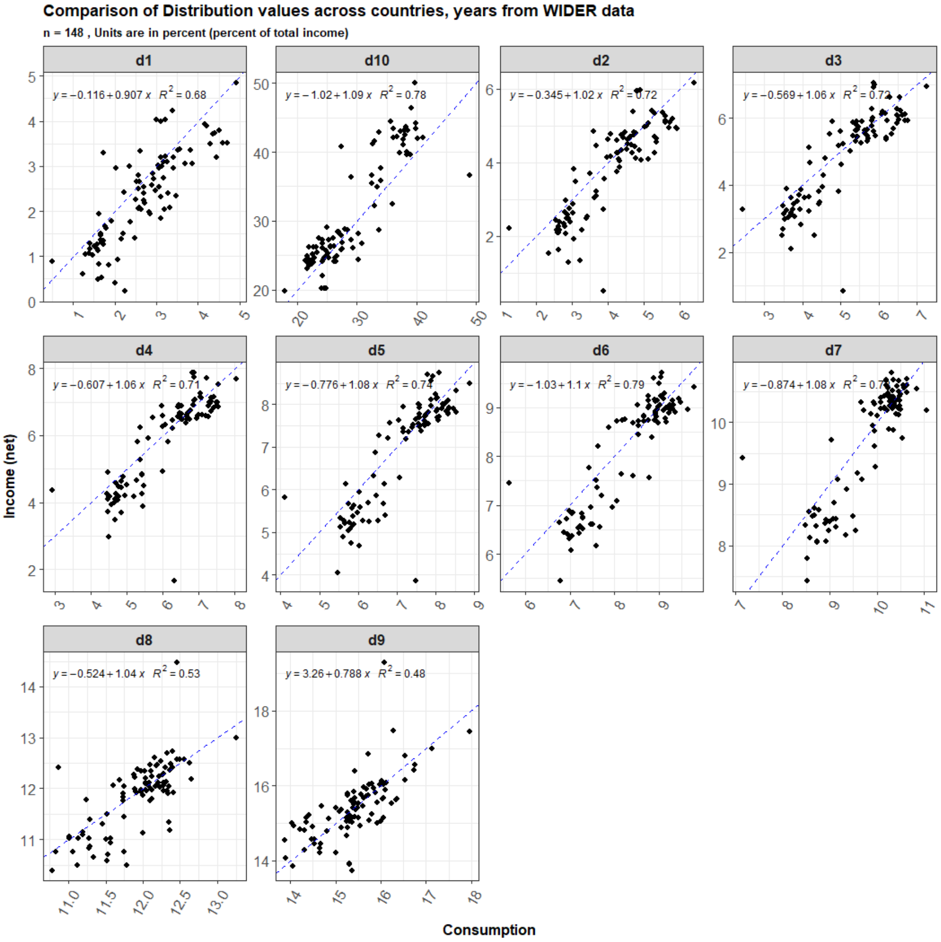

Figure 3:Consumption distribution deciles (x axis) compared to Net income distribution deciles (y axis) across all country-year observations. Dashed lines show the 1:1 linear relationship. Solid line is the used regression line. Only observations for half the dataset are selected (Pre 2004) for the plot

Consumption distribution deciles are converted into net income deciles using the equation (1) (which was fit using a linear regression for each decile) below,

$$D_{netincome_{n,r,t}} = \cancel{Coeff}a_n * D_{consumption_{n,r,t}} + \cancel{I}b\cancel{ntercept}_n \qquad (1)$$

where,

D is the share of consumption or income in a particular decile between 0 and 100,

~~Coeff~~ *a* is the coefficient applied to each decile parameterized using a linear regression, documented in Table 4 below (). ~~,~~

Decile	Intercept	Coefficient	Adjusted R^2
1	-0.02	0.81	0.~~5~~68
2	-0.39	1.00	0.72~~64~~
3	-0.65	1.06	0.72~~69~~
4	-0.76	1.08	0.71~~2~~
5	-0.91	1.10	0.74~~5~~
6	-1.12	1.12	0.7~~8~~9
7	-1.10	1.10	0.7~~8~~5
8	-0.74	1.06	0.~~66~~53
9	4.81	0.69	0.~~29~~48
10	-1.39	1.11	0.7~~5~~8

Table 4: Summary of coefficients and intercepts by decile used by Equation 1. These are fit based on 148 data points.

~~Intercept~~ *b* is derived from linear regressions run for each decile, documented in Table 4,

n is the decile ranging from 1 to 10, and

r, *t* are the region and the time step respectively.

Validation of our approach- We then verified the performance on our regression on a testing dataset (Figure 4). We note that the R squared values in our testing dataset is similar to our training dataset and we also noted that the imputed values are within a 5 percent confidence interval of actual values. To validate our imputation method we calculated errors (Imputed shares- actual shares) for our testing dataset (n=109). We compared the error by decile for the dataset (***See SI Figure 1***). The mean error across deciles is generally within half a percent across all years. There are larger differences for the year 2011, where we had very few observations. We have also verified that all imputed decile values add up to 1.

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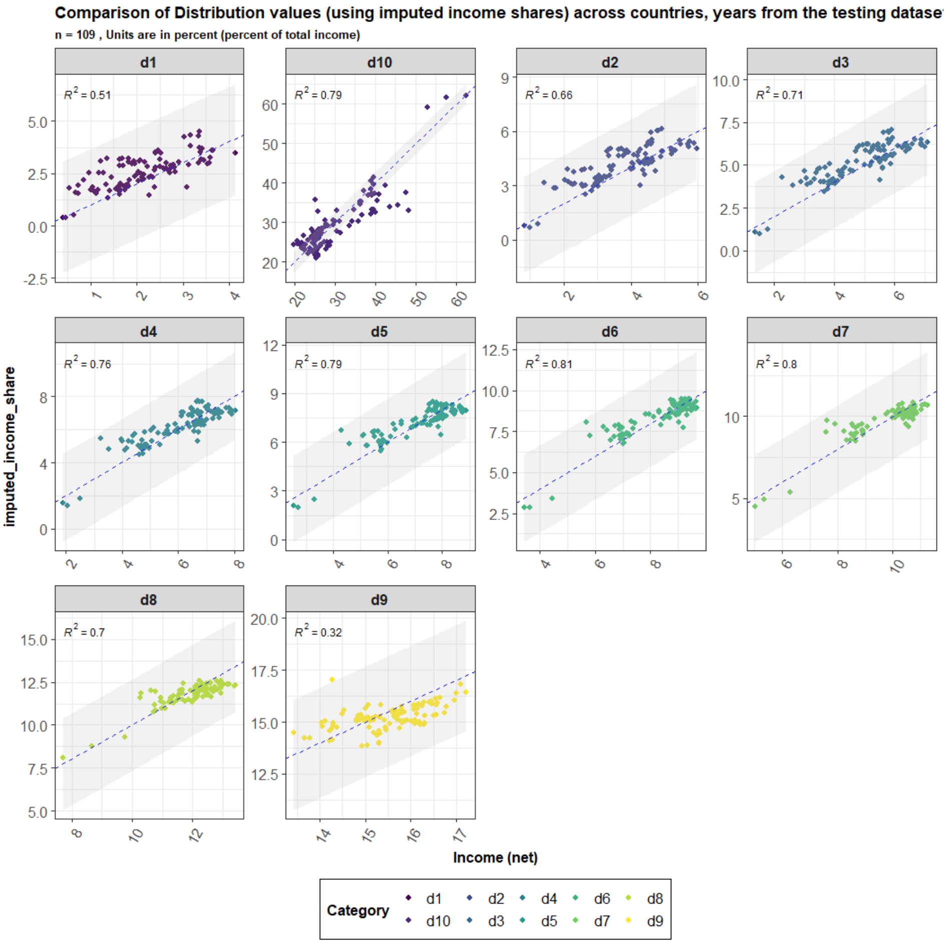


Figure 4: Comparison of actual vs imputed values on our testing dataset. Different deciles are shown as facets and we also show the confidence interval. All imputed values are found to be within a 5 % CI of the original values.

We note that this imputation method is applied to a small subset of observations (394) out of the total observations in our dataset 8522. We also acknowledge that this method is simple and should be improved upon in future updates/analysis.

~~Decile~~	~~Intercept~~	~~Coefficient~~	~~Adjusted R^2~~
~~1~~	~~-0.02~~	~~0.81~~	~~0.5~~
~~2~~	~~-0.39~~	~~1.00~~	~~0.64~~

~~3~~	~~-0.65~~	~~1.06~~	~~0.69~~
~~4~~	~~-0.76~~	~~1.08~~	~~0.72~~
~~5~~	~~-0.91~~	~~1.10~~	~~0.75~~
~~6~~	~~-1.12~~	~~1.12~~	~~0.78~~
~~7~~	~~-1.10~~	~~1.10~~	~~0.78~~
~~8~~	~~-0.74~~	~~1.06~~	~~0.66~~
~~9~~	~~4.81~~	~~0.69~~	~~0.29~~
~~10~~	~~-1.39~~	~~1.11~~	~~0.75~~

~~*Table 4: Summary of coefficients and intercepts by decile used by Equation 1. These are fit based on 257 data points.*~~

2.4 Imputing net income deciles based on summary measures of the GINI coefficient.

As observed in Table 1, the majority of observations in our dataset are those from the imputation from the GINI coefficient. In this section we will explain this imputation approach, why a new imputation approach was necessary and why this approach is an improvement upon existing methods.

For many countries, years, no data are available for the income or consumption deciles based on household survey data. However, World Development Indicators (WDI) dataset (Reid, 2012) do provide aggregate measures of the income distribution such as the GINI coefficient for some country-year observations[1]. Many studies have utilized the GINI coefficient in combination with different functional forms to estimate the underlying income distribution (Shorrocks & Wan, 2008; Soergel et al., 2021). Most prominent amongst these methods is the usage of the lognormal functional form along with the GINI coefficient to derive the underlying distribution.

However, methods such as the lognormal functional form have documented limitations. For example, the observations are known to deviate from the lognormal in the tails of the distribution(Badel et al., 2020; Chotikapanich, 2008). Moreover, the lognormal functional form is assumed for every country for every year. Recently, a non-parametric approach was developed which uses the GINI coefficient in combination with a two-component model based on a principal components analysis (PCA) to produce a more accurate estimate of income deciles (Narayan et al., 2023). This method addresses some of the limitations of the lognormal functional form. The performance of the non-parametric PCA based approach compared to the lognormal functional form is described in more detail in Figure 5 below. We found that the PCA based approach improves the fit across several deciles compared to the lognormal functional form. The paper by Narayan et al. (2023) contains a more extensive discussion on the model fit and comparisons of fit across countries ,years and individual deciles. Given that the method provided a good fit to the historical data on income distributions, we use this method to impute income deciles where only the GINI is available.

[1] The WDI dataset has observations of the GINI coefficient from various research studies. However, the underlying income concept of the GINI coefficient is not always available.

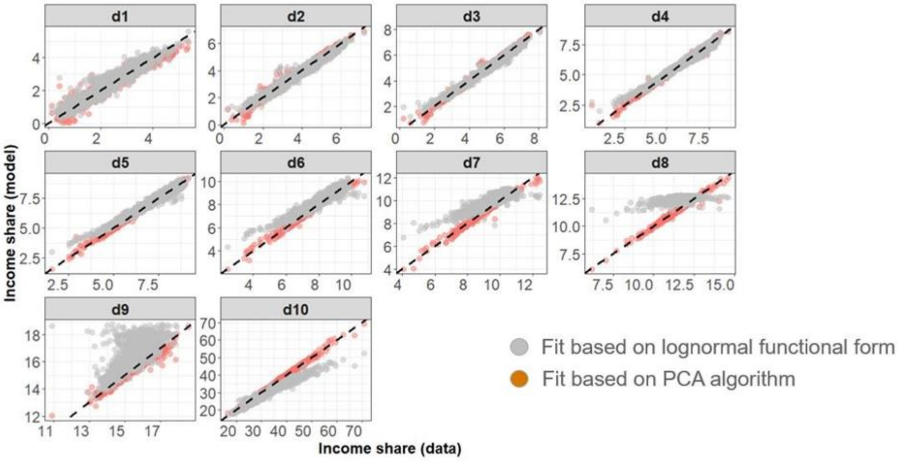


Figure 5: Comparison of fit of lognormal functional form (grey dots) with PCA based fit (orange dots) with data for each decile (facet). Lines represent 1 to 1 fit between x and y axis. Income shares are expressed as a percent of total income.

For country-years where we could not find data on net income or consumption, we used this PCA based approach along with observed values of the GINI coefficient from the World Development Indicators Database (Reid, 2012) to impute the underlying net income distribution.

The PCA based approach can be described as follows.

The income deciles are calculated as

$$D_{r,t} = a_{r,t}PC1 + b_{r,t}PC2 \qquad \textit{(2)}$$

Where,

D is a 10-dimensional vector of income shares for all population deciles in region r at time t.

PC1 and PC2 are the two principal components, also vectors of length 10 (Values of PC1, PC2 are provided in **SI 2 Figure 2, SI 2 Table 3**)

a and b are coefficients of the two principal components specific to each region and time

The coefficient *a* is derived from the GINI coefficient using a regression equation estimated on **1659** observations of national net income distribution

$$a_{r,t} = -11.4815 + 29.71708 * GINI_{r,t} \qquad (3)$$

And the coefficient *b* is estimated using lagged values of the Palma Ratio (d10/(d1+d2+d3+d4)) and income share in the ninth decile and the current period labor share of GDP

$$b_{r,t} = -17.18222 + \left(1.07957 * \ LabShareGDP_{r,t}\right) + (113.10810 * Ninth\ Decile_{t-1}) + \left(-0.36392 * PalmaRatio_{r,t-1}\right) \qquad (4)$$

Using this approach, we were able to fill in values for various country-years. The observations in our dataset are now summarized in Table 1 above.

As mentioned and discussed above, the PC algorithm used for the imputation was tested against the latest data on decile level income distributions and provided a good fit for all deciles across all countries. This testing was performed both for in sample and out of sample observations. This PCA based method was also found to yield a better fit to the data when compared to other methods such as using a GINI coefficient in combination with a lognormal functional form.

Since we used a summary measure (GINI coefficient) to derive the underlying distribution, we also validated our imputation approach by recalculating the GINI coefficient from the imputed distribution and comparing it with the reported GINI coefficient (Figure 6). We observe that our re-calculated values largely have a one-to-one correlation with the input GINI values suggesting that the imputation did not introduce many errors (overall R squared value of the comparison is 0.99). However, the relationship does start to weaken for countries with very high GINI coefficients such as South Africa where the recalculated GINI coefficient is different from the observed GINI coefficient by as much as 0.07 points. This is a result of the parameters of the PCA algorithm which do not reproduce well values for outlier countries with extreme GINI coefficients. We also observe that the re-calculated GINI coefficients for some countries are different in different years. For example, in Malawi, there are large year to year jumps in the reported GINI coefficients from year to year (**SI 2 Figure 3**).

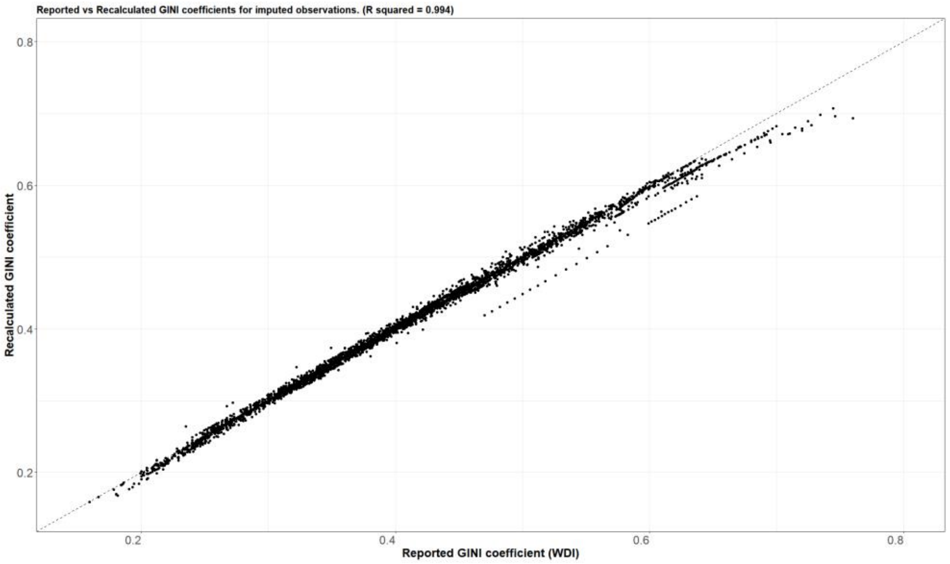


Figure 6: Comparison of the reported GINI coefficients from the WDI (x axis) with the recalculated GINI coefficients from the imputed distribution (y axis). Each dot is a country-year observation. The dashed line represents a one-to-one relationship.

We also evaluated temporal trends in the complete dataset which now include values from direct observations and also imputed values. The top two panels in Figure 5 below shows trends in the income shares for the 10th decile for India and China across time from all data sources.

This approach helps us generate better coverage in our dataset and the PCA model provides a statistically valid method to generate the data from GINI coefficients. This approach does have some limitations, however. The GINI coefficients from the WDI can represent multiple income concepts. For example, in the US, the GINI from the World Development Indicators database is based on gross income and the income distribution based on surveys (From LIS) is for net income, i.e., it includes adjustments for direct taxation[2]. Moreover, it is unclear when the GINI coefficients are based on simple interpolation or country level/subnational survey data. This further makes it important to understand/document the source of the GINI coefficients used clearly.

As a first step in in addressing this, we used data from the “All the GINIs” dataset which clearly specifies the income concept of the derived GINI coefficient (G. Ferreira et al., 2015; Smeeding & Latner, 2015), to identify the income concepts of the GINIs used for interpolation. Based on that, we identified that roughly 4200 observations of the GINIs used for imputation are net income GINIs while the remaining are consumption/expenditure GINIs or Gross income GINIs

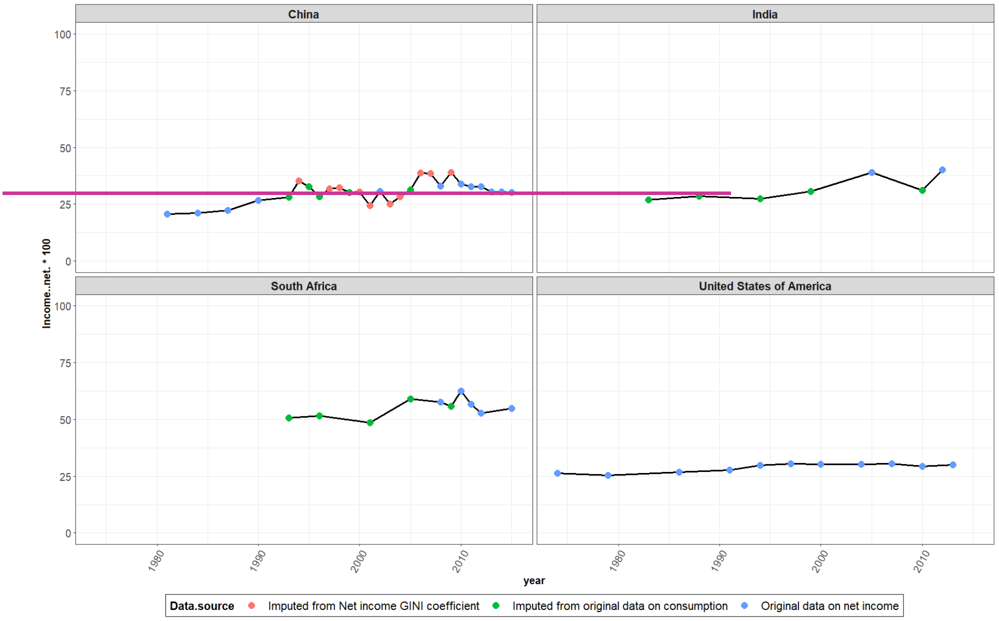
[2] Note that the examination of the metadata for the LIS values for the US shows that the values are computed as the gross income distribution minus an imputed tax adjustment.

(Table 5). Therefore, data points when derived from imputation of a consumption/expenditure/gross income GINI have been marked as such in our final dataset. Users can choose to use all data points together or filter data depending upon their needs.

Type of imputation	values
Imputed from Net income GINI	4201
Imputed from Expenditure and Consumption GINI	1303
Imputed from Gross income GINI	1333
Total	**6837**

Table 5: Description of source of GINI used for imputation

Given that the “All the GINIs" dataset still offers only a limited time series, this still suggests a limitation in our imputation approach and one possible next step would be to only use net income GINIs for the imputation of the decile level income distribution. Figure 7 below shows the full time series of our dataset based on different types of imputation performed.



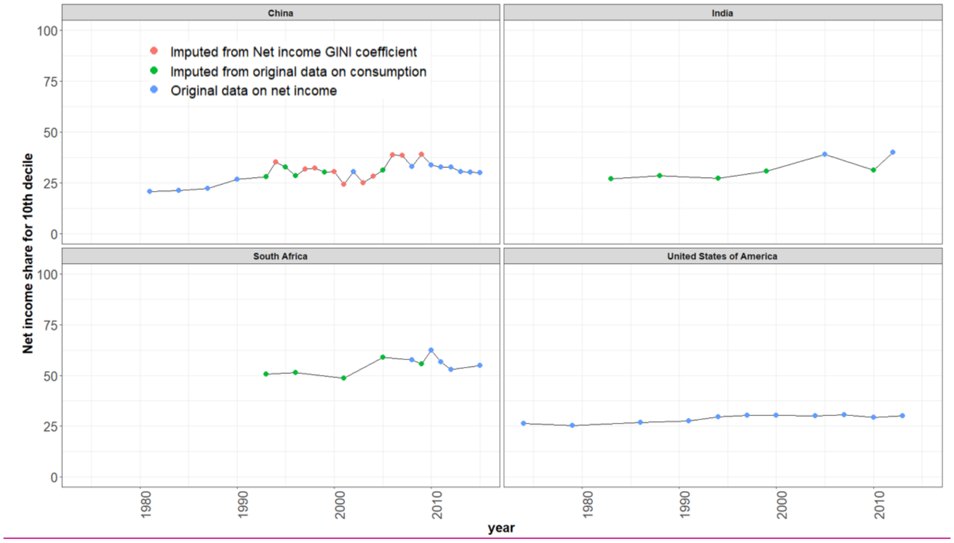


Figure 7: Temporal trends in the 10th decile for the complete dataset. Colors represent different data sources.

3. Aggregating income distributions to the regional level

The motivation for developing this country-level dataset was to initialize decile level income distribution values for the Global Change Analysis Model (GCAM). Models like GCAM operate on regional boundaries and therefore would require the income distributions to be aggregated to their respective regional boundary conditions. We aggregated the income distributions from the country level to 32 geographic regions represented by GCAM. The 32 regions are shown as a map in Figure 8.

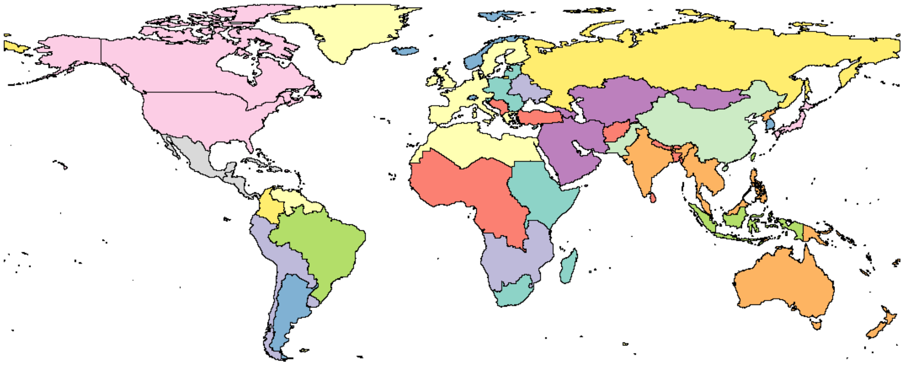


Figure 8: Map of the 32 GCAM regions. These 32 GCAM regions are based on 229 country boundaries.

Aggregating income distributions to the regional (where a region is made up of multiple countries) level is not straightforward because countries within regions differ in population size, average income level, and level of inequality in the income distribution. For example, an individual who belongs to the 10th decile in Romania would not necessarily be counted amongst the 10th decile of Europe as a whole, given the difference in the overall income level of Romania relative to higher income level of other European countries such as Germany and France. Similarly, even countries with similar average income levels may differ significantly in how income is distributed across deciles.

The aggregation of the country level income distributions to the regional income distributions involved the following steps:

1. First, we sorted all country net-income deciles in the region by the average decile income level, from lowest to highest income (The net income distribution shares are applied to this GDP per capita, measured in at PPP (2011 USD) to arrive at the income level). We use GDP per capita here, since that variable is the income proxy in GCAM.

2. Next, we calculated the cumulative population for each of these country income groups. The cumulative population over all country income groups matches the regional total population.
3. We then calculated cumulative population cutoffs that would create regional population deciles by dividing the regional population by 10.
4. Based on these cutoffs, we calculated the regional decile shares of income by assuming a uniform distribution of income within each country-decile. Thus, wherever a country decile spanned a regional cutoff, its income was split between regional deciles in proportion to the country population falling in each regional decile.

Figure 9 below illustrates our aggregation approach for GCAM region 14, Europe Non-EU, which is made up of Albania, Bosnia, Croatia, Macedonia, Montenegro, Serbia and Turkey. The figure demonstrates that a given regional decile can contain a mix of deciles at the country level. For example, the regional d2 consists of d3 and d4 values of some low-income countries such as Serbia and Albania. The regional d10 contains both the d9 and d10 values from Tukey.

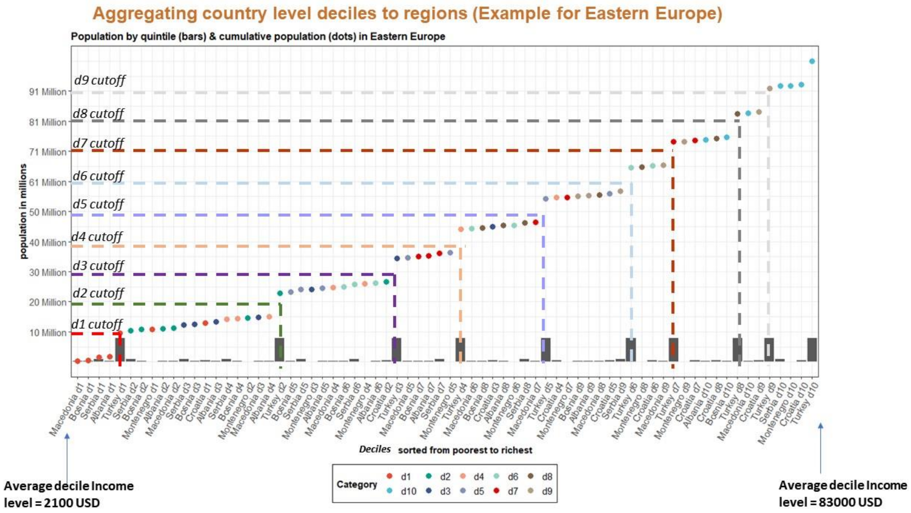


Figure 9: Explanation of our aggregation approach. On the x axis all deciles within the region are sorted from low income to high income. Bars track the population. The dots show the cumulative population compared to the decile level income. Dashed lines show the new regional cutoffs for the deciles.

We also compared the aggregated income distribution to the country level income distributions for 2015 (Figure 10). We find that the aggregated income distributions are mostly driven by trends in the income distribution of the most populous countries in the region, as expected. In the example above, the income distribution for GCAM region 14 (Europe Non-EU) is largely driven by the income distribution of Turkey, which is the most populous, and most unequal, country in that region (e.g., Turkey represents approximately 75% of the regional population in 2015). There are certain cases where the regional distribution is significantly different than the country-level distributions. In Central Asia for example, the regional income distribution is much more unequal (regional GINI is 0.53) compared to the country level GINIs (Highest GINI is 0.39). This is because there is considerable variation in the income levels across countries. The country-level average incomes range from USD 2011 in Tajikistan to USD 23485 in Uzbekistan. This further illustrates why a specific aggregation method was necessary to construct these regional income distributions (Simple aggregation methods would miss such intra-regional dynamics).

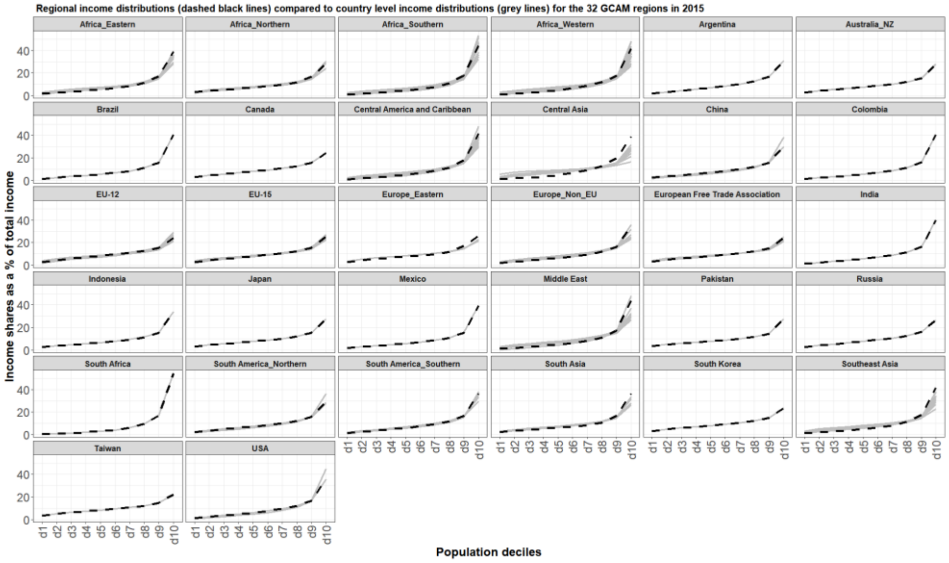


Figure 10: Regional income distributions (Dashed black line) compared to the national income distributions (grey lines) in each of the 32 regions in 2015.

4. **Quantifying coverage and assessing regional bias in the data**

As mentioned earlier, we intended to develop a dataset for net income distribution for the 229 countries aggregated to 32 regions used in GCAM. As shown in Table 5, we were unable to find any data on net income or consumption for 39 of those 229 countries. Previous models that have been developed for projecting income distributions have been based largely on data for high income countries (Rao et al., 2019; Sauer et al., 2020).

In order to evaluate whether the lack of data for the 56 countries introduces a bias, we assessed the data coverage in terms of percent of global population (total population of 229 countries) and percent of global GDP (total GDP at MER for 229 countries) for our dataset. We found that our dataset covers 98% of the global population and 93% of the global GDP in any given year.

Similarly, we also compared the ~~average~~ population and GDP of countries with and without data for ~~five~~ two years (**Table 6**) and found that the ~~average population of countries with data in the last historical year, i.e., 2015, is significantly higher (19 times) than the average population of countries without data. Similarly, the average GDP of countries with data is roughly 4.5 times the average GDP of countries without data.~~countries that are missing data in the latest historical year (2015) only constitute 1.3% of the global population and 0.3% of the global GDP. The biggest countries that are missing data in terms of population in 2015 are Morocco (33 million people), North Korea (24 million people) and Somalia (10 million people). In terms of GDP, the biggest countries missing are Morocco (123 billion USD at PPP), Oman (68 billion USD at PPP) and Equatorial Guinea (18 billion USD at PPP).

~~-~~	~~Average national population (in thousands)~~		~~Average national GDP at MER (Billion 2010 USD)~~	
~~Year~~	~~Data available~~	~~Data not available~~	~~Data available~~	~~Data not available~~
~~2010~~	~~37988~~	~~2835~~	~~370~~	~~90~~
~~2011~~	~~38881~~	~~2777~~	~~385~~	~~90~~
~~2012~~	~~39351~~	~~2808~~	~~394~~	~~90~~
~~2013~~	~~39822~~	~~2838~~	~~404~~	~~91~~
~~2014~~	~~40066~~	~~2915~~	~~414~~	~~91~~
~~2015~~	~~40610~~	~~2063~~	~~423~~	~~93~~

Country data status	**year**	**Global GDP|PPP**	**Global Population**
Data not available	**2010**	**0.4%**	**2.0%**
Data not available	**2015**	**0.3%**	**1.3%**
Imputed from GINI coefficient (using PCA algorithm)	2010	19.9%	25.8%
Imputed from GINI coefficient (using PCA algorithm)	2015	45.1%	52.5%
Imputed from original data on consumption (Using regression)	2010	10.8%	31.2%
Imputed from original data on consumption(Using regression)	2015	5.8%	9.6%
Original data on net income	2010	68.9%	41.0%
Original data on net income	2015	48.8%	36.6%

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Table 6: ~~Comparison of national average population and national average GDP (at MER) for countries with and without data for five historical years.~~ Coverage by data status in terms of GDP in PPP and Population from the SSP database V9.

Further , Figure 11 below shows the data availability status (from Table 6) as a map, to show the status of data availability by ISO code.

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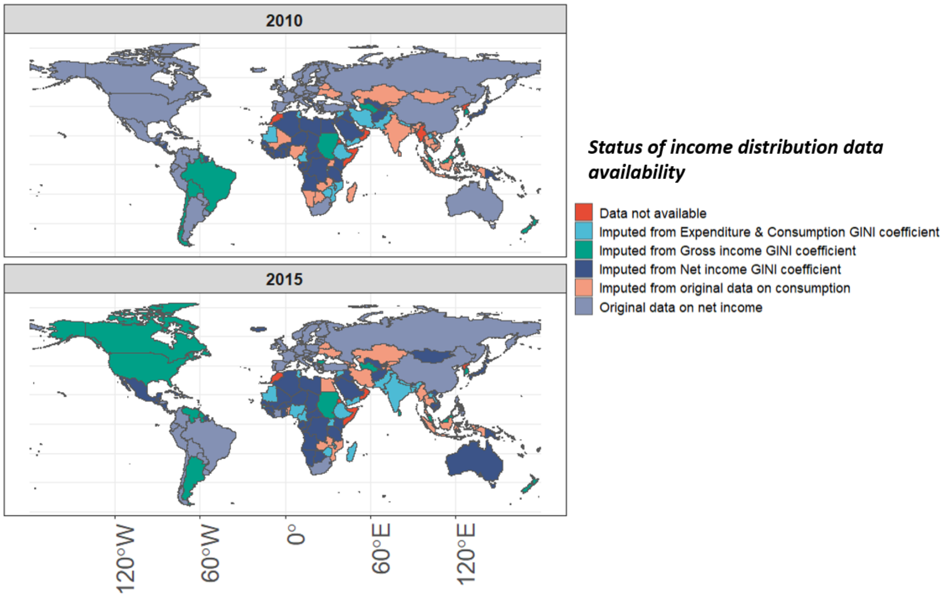
2010
2015
120°W
60°W
0°
60°E
120°E
Status of income distribution data availability
🟥 Data not available
🟦 Imputed from Expenditure & Consumption GINI coefficient
🟩 Imputed from Gross income GINI coefficient
🟦 Imputed from Net income GINI coefficient
🟧 Imputed from original data on consumption
🟪 Original data on net income

Figure 11:Data availability by country. Availability is shown here for two years 2010 and 2015.

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Since this data will be used to initialize income distributions in the GCAM model, we also evaluated whether the data would introduce a bias for any GCAM region (e.g., is there no coverage or poor data coverage for any given GCAM region).

To evaluate this, we divided the countries in our dataset into the 32 geographical regions modelled by GCAM. We then assessed the data coverage in terms of a percent of population (SI 3 Table 4) and GDP (SI 3 Table 5) for each of these regions. While these regions are specific to a particular model, they also well represent heterogeneity across countries in terms of regional economic and demographic conditions.

An example of a result of this assessment is that in the region of Africa Eastern we found data that covers 64% of the region's population in 2010 and 40% of the region's GDP for the same year. We performed this assessment for 5 years from 2010 to 2015. The purpose of this assessment is to verify whether we have some coverage of data for all regions of the world within those 5 years which would increase our confidence that our models are not biased towards high income countries. The lowest coverage in our dataset is found for the Middle East region where our data covers roughly 60% of the region's population and 40% of the region's GDP.

5. Discussion

In this paper we present a new consistent dataset on the net income distribution across 190 countries from 1958-2015. This dataset is also available for 32 aggregated regions. To our knowledge there is no other dataset that presents consistent data at multiple geographical scales that has been documented in a peer-reviewed article. This complete and harmonized dataset may be useful for efforts related t modelling of the net income distribution.

The aggregation method presented in this paper (section 3) takes into account both within-country and across-country inequality when aggregating income distributions to regional boundaries. This is important to regions where there is significant diversity in the income distribution across countries such as Central Asia, where the aggregated income distribution is significantly more unequal than any of the member countries (Figure 10).

There are a number of areas of improvement that we have noted that can be explored as next steps or in future updates to this dataset. First, we have used a simple linear regression approach when converting the consumption distributions to net income distribution. This can be improved upon if more data becomes available related to the savings rate across countries or if the income within countries can be broken down into the various incomes and expenditures similar to a Computable General Equilibrium (CGE) framework.

Similarly, while our imputation approach greatly increased spatio-temporal coverage in our dataset, we noticed that the GINI values from the WDI can represent multiple income concepts. In the future, these gross income or consumption GINIs should also be converted to net income GINIs before the imputation. This would require more detailed data on the input GINI coefficients. One possible next step would be to construct a method for such a conversion using GINI values from datasets such as the "All the GINIs" dataset which tracks the type of the GINI coefficient (G. Ferreira et al., 2015; Smeeding & Latner, 2015). Another option would be to explicitly generate a tax adjustment to convert gross income values to net income.

We further note that we utilized a single equivalence scale to represent our income distributions (per capita). However, we have not tested the effect of changing equivalence scales on income distributions. This can be tested in the future.

We further found that the PCA based imputation approach generates some error when imputing the income distributions of highly unequal regions such as South Africa. As more data on income distributions becomes available, the PCA algorithm can be re-parameterized to newer data. When this happens, the imputation should be re-performed.

Finally, the data generation described above is documented as an open-source workflow of a software package called *pridr* which can be used to generate and re-aggregate these data. The software package is available on GitHub and the dataset itself is available as a version-controlled release on Zenodo (See data availability statement below).

6. Data availability

The main dataset is available here on Zenodo- https://zenodo.org/record/7093997 (Narayan et al. 2022) There are 2 main datasets available –

1. 32 region income deciles from 1958 to 2015
2. ISO level income distributions from 1958-2015

~~2.~~ Note that the income distributions data can be flexibly generated using the pridr software package available on GitHub here- https://github.com/JGCRI/pridr

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Competing interests

The authors declare that none of the authors have any competing interests.

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References

Babones, S. J., & Alvarez-Rivadulla, M. J. (2007). Standardized income inequality data for use in cross-national research. *Sociological Inquiry*, *77*(1), 3-22.

Badel, A., Huggett, M., & Luo, W. (2020). Taxing top earners: a human capital perspective. *The Economic Journal*, *130*(629), 1200-1225.

Bank, W. (2015). PovcalNet. In.

Calvin, K., Patel, P., Clarke, L., Asrar, G., Bond-Lamberty, B., Cui, R. Y., Di Vittorio, A., Dorheim, K., Edmonds, J., & Hartin, C. (2019). GCAM v5. 1: representing the linkages between energy, water, land, climate, and economic systems. *Geoscientific Model Development*, *12*(2), 677-698.

Chotikapanich, D. (2008). *Modeling income distributions and Lorenz curves* (Vol. 5). Springer Science & Business Media.

Deaton, A., & Zaidi, S. (2002). *Guidelines for constructing consumption aggregates for welfare analysis* (Vol. 135). World Bank Publications.

Frank, M. W. (2009). Inequality and growth in the United States: Evidence from a new state-level panel of income inequality measures. *Economic Inquiry*, *47*(1), 55-68.

Fujimori, S., Hasegawa, T., & Oshiro, K. (2020). An assessment of the potential of using carbon tax revenue to tackle poverty. *Environmental Research Letters*, *15*(11), 114063.

G. Ferreira, F. H., Lustig, N., & Teles, D. (2015). Appraising cross-national income inequality databases: An introduction. *The Journal of Economic Inequality*, *13*, 497-526.

Hallegatte, S., & Rozenberg, J. (2017). Climate change through a poverty lens. *Nature Climate Change*, *7*(4), 250-256. https://doi.org/10.1038/nclimate3253

Hughes, B. B. (2019). *International futures: Building and using global models*. Academic Press.

Jafino, B. A., Walsh, B., Rozenberg, J., & Hallegatte, S. (2020). Revised estimates of the impact of climate change on extreme poverty by 2030.

Lakner, Christoph, Branko Milanovic, and Branko Milanovic. "World Panel Income Distribution (LM–WIPD)." Washington, DC: The World Bank (2013).

Narayan, K. B., O'Neill, B. C., Waldhoff, S. T., & Tebaldi, C. (2023). Non-parametric projections of national income distribution consistent with the Shared Socioeconomic Pathways. *Environmental Research Letters*, *18*(4), 044013.

Narayan, K. B., O'Neill, B. C., Waldhoff, S., and Tebaldi, C.: A consistent dataset for net income deciles for 190 countries, aggregated to 32 geographical regions and the world from 1958-2015 (1.0.0), https://doi.org/10.5281/zenodo.7093997, 2022.

Piketty, T., & Saez, E. (2003). Income inequality in the United States, 1913–1998. *The Quarterly journal of economics*, *118*(1), 1-41.

Rao, N. D., & Min, J. (2018). Less global inequality can improve climate outcomes. *Wiley Interdisciplinary Reviews: Climate Change*, *9*(2), e513.

Rao, N. D., Sauer, P., Gidden, M., & Riahi, K. (2019). Income inequality projections for the Shared Socioeconomic Pathways (SSPs). *Futures*, *105*, 27-39. https://doi.org/https://doi.org/10.1016/j.futures.2018.07.001

Ravallion, M. (2015). The Luxembourg Income Study. *The Journal of Economic Inequality*, *13*(4), 527-547. https://doi.org/10.1007/s10888-015-9298-y

Reid, C. D. (2012). World development indicators 2011. *Reference Reviews*, *26*(8), 26-27.

Sauer, P., Rao, N. D., & Pachauri, S. (2020). WIDER Working Paper 2020/65-Explaining income inequality trends: an integrated approach.

Shorrocks, A., & Wan, G. (2008). *Ungrouping income distributions: Synthesising samples for inequality and poverty analysis* (929230058X).

Smeeding, T., & Latner, J. P. (2015). PovcalNet, WDI and 'All the Ginis': a critical review. *The Journal of Economic Inequality*, *13*(4), 603-628.

Smeeding, T. M., & Grodner, A. (2000). Changing Income Inequality in OECD Countries: Updated Results from the Luxembourg Income Study (LIS). In (pp. 205-224). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-57232-6_10

Soergel, B., Kriegler, E., Bodirsky, B. L., Bauer, N., Leimbach, M., & Popp, A. (2021). Combining ambitious climate policies with efforts to eradicate poverty. *Nature Communications*, *12*(1). https://doi.org/10.1038/s41467-021-22315-9

Van der Mensbrugghe, D. (2015). Shared socio-economic pathways and global income distribution.