Supplementary Appendix

Contents

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1. Measures and Domains in the Aging Society Index

When assessing the aging of societies and their capacity to support older populations, we sought to develop an evidence-based metric to assess the status of older populations across countries, and within countries across a series of economic and social domains in order to compare countries' success in adapting to population aging. The metric would serve both as a guide to inform policies for forging a productive and equitable aging society and as a tool to assess their effectiveness over time.

The Research Network on an Aging Society, a fourteen-member interdisciplinary group of geriatricians, demographers, sociologists, economists, psychologists, and policy experts, working from the framework of the well-established Successful Aging paradigm (1). We formulated an evidence-based model of a successfully aging society. We defined with the following five major components for the successful aging of a society:

- PRODUCTIVITY AND ENGAGEMENT – a successfully aging society facilitates the engagement of older persons in society, either through work for pay or volunteering (2-7);
- WELL-BEING - a successfully aging society provides health care informed by a sophisticated understanding of the health care needs of older persons (8, 9);
- EQUITY- a successfully aging society distributes resources equitably across the older population thus lessening the gap between the 'haves' and the ' have nots' (10, 11);
- COHESION – a successfully aging society maintains social connectedness and solidarity, within and between generations (12-14) and
- SECURITY- a successfully aging society provides economic and physical security for older persons (15).

The Index has five major domains, each corresponding to one of our five central components of a successfully aging society. The data for each domain includes between two and five specific measures available for all OECD countries we studied. The Aging Society Network determined the measures and relative weights within each domain, and a weight for each of the five domains within the overall Index (Fig. 1). Details of each measure is reported in Table 1.

Fig. 1. Measures in the Aging Society Index

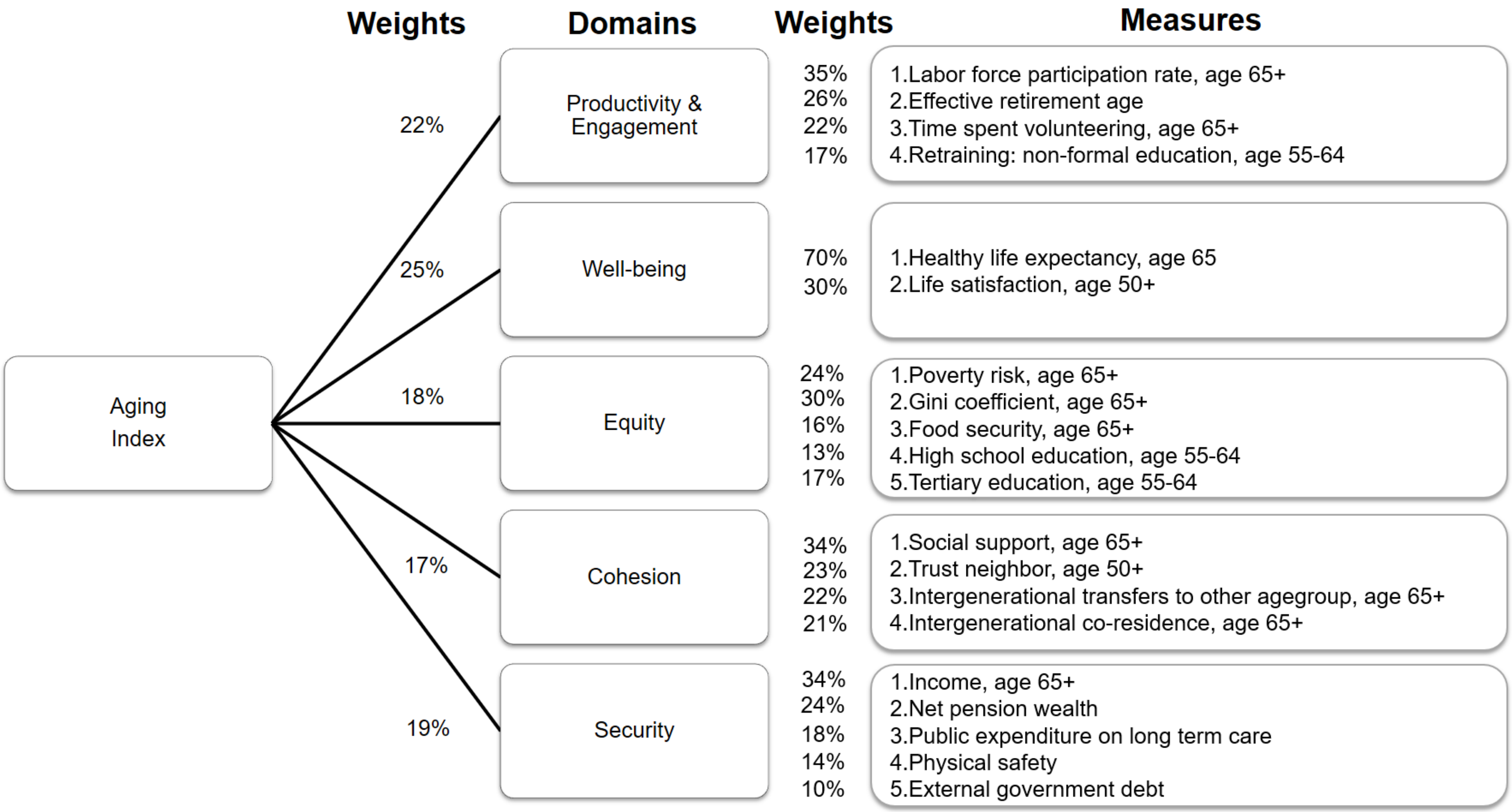


Table 1. Measures and data sources

PRODUCTIVITY AND ENGAGEMENT
Labor force participation rate for people aged 65+ The proportion of population age 65+ in the labor force, OECD
Effective retirement age The effective age at which older workers withdraw from the labor force, OECD
Time spent volunteering for people aged 65+ Average minutes of volunteering per day, OECD
Retraining: Non-formal education for people aged 55 to 64 Proportion of the population aged 55-64 that participated in non-formal education, OECD
WELL-BEING
Objective well-being: Healthy life expectancy at aged 65 Average number of years that a person aged 65 is expected to live in a state of good health, OECD
Subjective well-being for people aged 50 and above: life satisfaction "All things considered, how satisfied would you say you are with your life these days?" (Gallup)
EQUITY
Gini coefficient for people aged 65 and older Degree of inequality of income distribution within a country, OECD
Poverty risk for people aged 65 and older Ratio of people whose income falls below the poverty line, taken as half the median household income of the total population, OECD.
Food security for people aged 65 and older Europe: the share of people living in households who cannot afford to eat a meal with meat, fish or protein equivalent every second day, Eurostat.
USA: households in which one or more people were hungry at times during the year because they could not afford enough food, USDA. Attained at least high school education for people aged 55 to 64
Proportion of the population aged 55-64 that has attained high school or higher education Attained at least tertiary education for people aged 55 to 64
COHESION
Trust neighbor for people aged 50 and older People aged 50 who responded that they trust their neighbor, World Value Survey
Social support for people aged 65 and older People who report having relatives or friends they can count on, OECD
Intergenerational transfers to other age group, aged 65+ Percentage of transfers elderly provides to other age group, National Transfers Account
Intergenerational co-residence for people aged 65+ Percentage of elderly staying with children, Countries' Census

SECURITY
Income for people aged 65+ The income of older people, comparing them with the population as a whole, OECD.
Net pension wealth Present value of the flow of pension benefits, taking account of the taxes and social security contributions that retirees have to pay on their pensions, National Transfer Account
Public expenditure on long term care (%GDP) Long-term care public expenditure (health and social components), as share of GDP, OECD
Physical safety Percentage of the population declaring feeling safe when walking alone at night in the city or area where they live, OECD
External government debt (%GDP) Country's external government debt as share of GDP, CIA.

2. Goalpost method

The specific measures within the domains were chosen by the Network members from the various measures for which data are available from all, or from a meaningful subset, of the OECD countries. The methodology to construct the Aging Society Index using the goalpost method can be divided into four steps below:

First, we convert all measures as positive indicators, where higher values indicate better outcomes in the aging society. For example, “poverty risk in the elderly” was expressed as “the proportion not at risk of poverty”.

Second, each positive indicator is standardized with a score of 0 for the worst performing country in the data set available and a score of 100 as the best performing countries. This is done by assigning a score of 0 to the minimum observed value across countries and a score of 100 to the maximum observed value. Having defined the maximum and minimum values, a specific country’s score can be calculated as follows:

$$Goalpost = \frac{actual - \min}{max - \min} * 100$$

For example, OECD data indicates that incomes of older people are on average lower than the total population. The lowest OECD country was Estonia where those over 65s had an income of 68.9% of the total population (given a score of 0). The highest income was Spain where elderly had an income of 95.9% income of the total population and given a score of 100. The incomes of the people over 65s in the U.S. had 92.1% income of the total population and given a score of 85.9 for this measure. For example, $goalpost_{USA_{income}} = \frac{92.1-68.9}{95.9-68.9} * 100 = 85.9$

Third, we calculate the domains scores as a weighted summation of the measures in each domain using weights below. The weights within each domains sum to 100%. There were a number of important considerations regarding weighting of the specific measures within a domain and across domains for the final Index.

We employed three weighting strategies. The first was to weigh all measures within a domain equally with all weights summing to 100%. Thus if a specific domain had four measures, each would have a weight of 25%. We also attribute weights to the measures based on the recommendations of the fourteen member Network members. Each Network member was asked to provide individual weights for each measure, and average weights were calculated. The same approach was taken to weighting the five domains included in the final Index (Table 2). The final method was to set the aging index as the minimum over the five domain scores. This weighting scheme will rank high only for countries with no weaknesses in their domain scores.

Table 2. Weights assigned to measures in Aging Society Index

Domains	Measures	Equal weights	Network weights
Productivity and Engagement (4 measures)	Labor force participation rate, aged 65+ (%)	25%	35%
	Effective retirement age	25%	26%
	Volunteering, aged 65+ (mins per day)	25%	22%
	Retraining, aged 55-64 (%)	25%	17%
Well-being (2 measures)	Healthy life expectancy, aged 65	50%	70%
	Life satisfaction, aged 50+	50%	30%
Equity	Gini, aged 65+ (%)	20%	30%

(5 measures)	Food insecurity, 65+ (%)	20%	16%
	Poverty risk, aged 65+ (%)	20%	24%
	Upper sec attainment, aged 5564 (%)	20%	13%
	Tertiary attainment, aged 5564 (%)	20%	17%
Cohesion (3 measures)	Social support, aged 50+ (%)	33%	56%
	Intergenerational co-residence, aged 65+ (%)	33%	21%
	Trust neighbor, aged 50+ (%)	33%	23%
Security (5 measures)	Income, aged 65+ (%)	20%	34%
	Net pension wealth	20%	24%
	External government debt (%GDP)	20%	10%
	Public expenditure on LTC as %GDP	20%	18%
	Feel safe walking at night	20%	14%

Finally, the overall composite index is calculated as the weighted summation of the five specific domain scores (in step 3). The network weights for domains are 22% for PRODUCTIVITY AND ENGAGEMENT, 25% for WELL-BEING, 18% for EQUITY, 17% for COHESION, and 19% for SECURITY. Equal weights across domains (20% each) were also used as robustness check. We also acknowledged the value of flexibility in weighting and have established an open-access website which will allow individuals to recalculate the index based on their desired weights (16).

It is important to note that maximum scores within each measure and domain are achievable as the best-performing country was used as a benchmark rather than some theoretical value.

3. Z-scores method

We compared the results from the above goalpost method to Z-scores method. This method was used to allow standardization of indicators with different types and scales. It provided a convenient way to normalize results by anchoring them around the mean. The methodology using the z-score method can be divided into four steps:

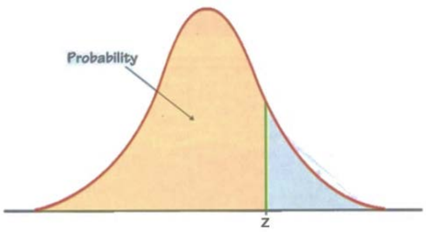
First, we convert all measures as positive indicators, where higher values indicate better outcomes in the aging society.

Second, each positive indicator is standardized using the z-score defined as follows:

$$Zscore = \frac{actual - \text{mean}}{standard\ deviation}$$

Third, the domain scores will be calculated as a weighted summation of the measures (in z-scores) using network or equal weights in Table 2.

Lastly, the composite aging index will be a weighted summation of domains z-scores. We converted the final z-scores into a probability ranging between 0 and 100% using the standard normal distribution.



4. Lowest domain method

We also compared the results using the minimum domain score from goalpost method as our index. This weighting scheme will rank high only for countries that have no weakness in their domain scores. This weighting produces a ranking where a low score in one domain cannot be offset by higher scores in other domains. The method was to set the aging index as the minimum over the five domain scores. This weighting scheme will rank high only for countries with no weaknesses in their domain scores. The motivation for this weighting scheme is that while high scores in all five domains imply high quality of life for the elderly, the low score cannot be offset by higher domains.

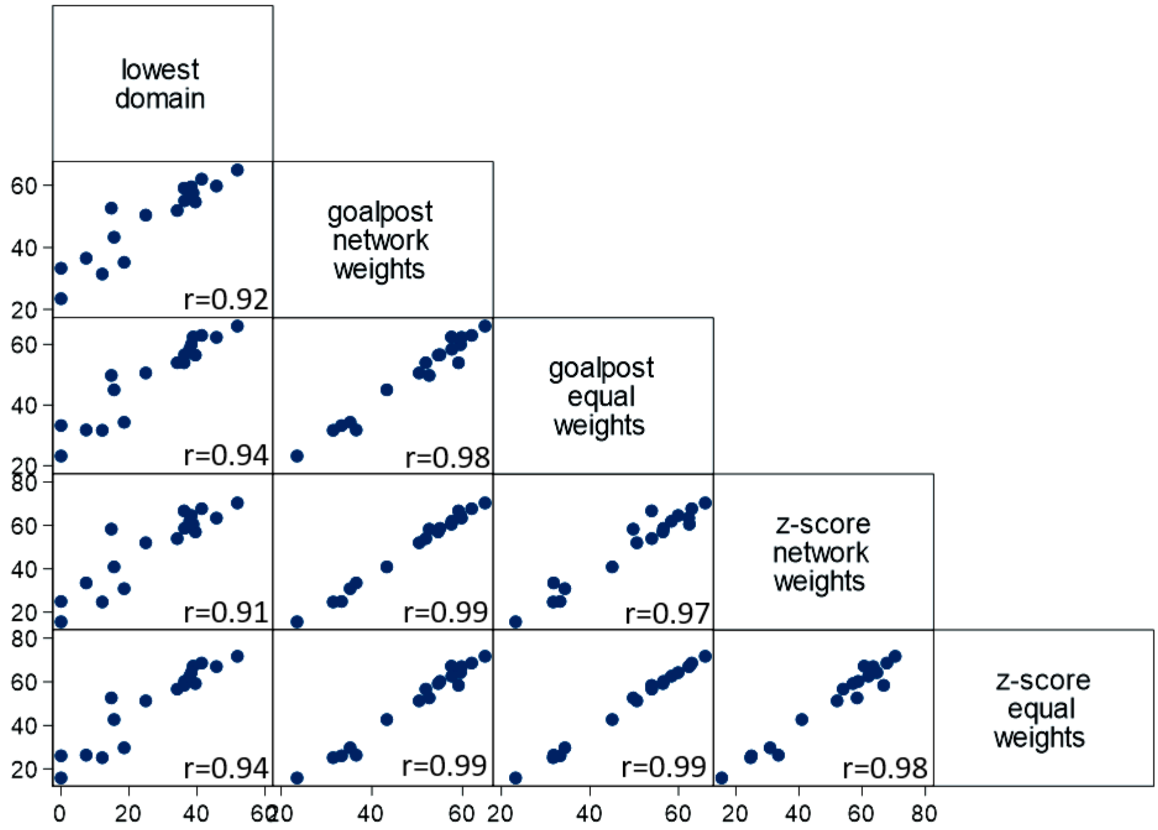
5. Robustness checks

We utilized three different analytical strategies detailed above (goal post, Z scores and lowest domain) to rank countries within each domain and overall. The composite Aging Society Index has a possible range of 0 to 100. There was a high degree of correlation across the three analytic strategies.

Fig. 2 illustrates the robustness of our composite index scores using different methods such as the widely used goalpost method, standardized Z-score, and the lowest domain. These comparisons resulted in high correlation. The correlation with the lowest domain was the poorest (Pearson correlation $r_p \geq 0.91$) as the lowest domain had limited information compared to the other methods that pooled the aging index across all domains ($r_p \geq 0.97$).

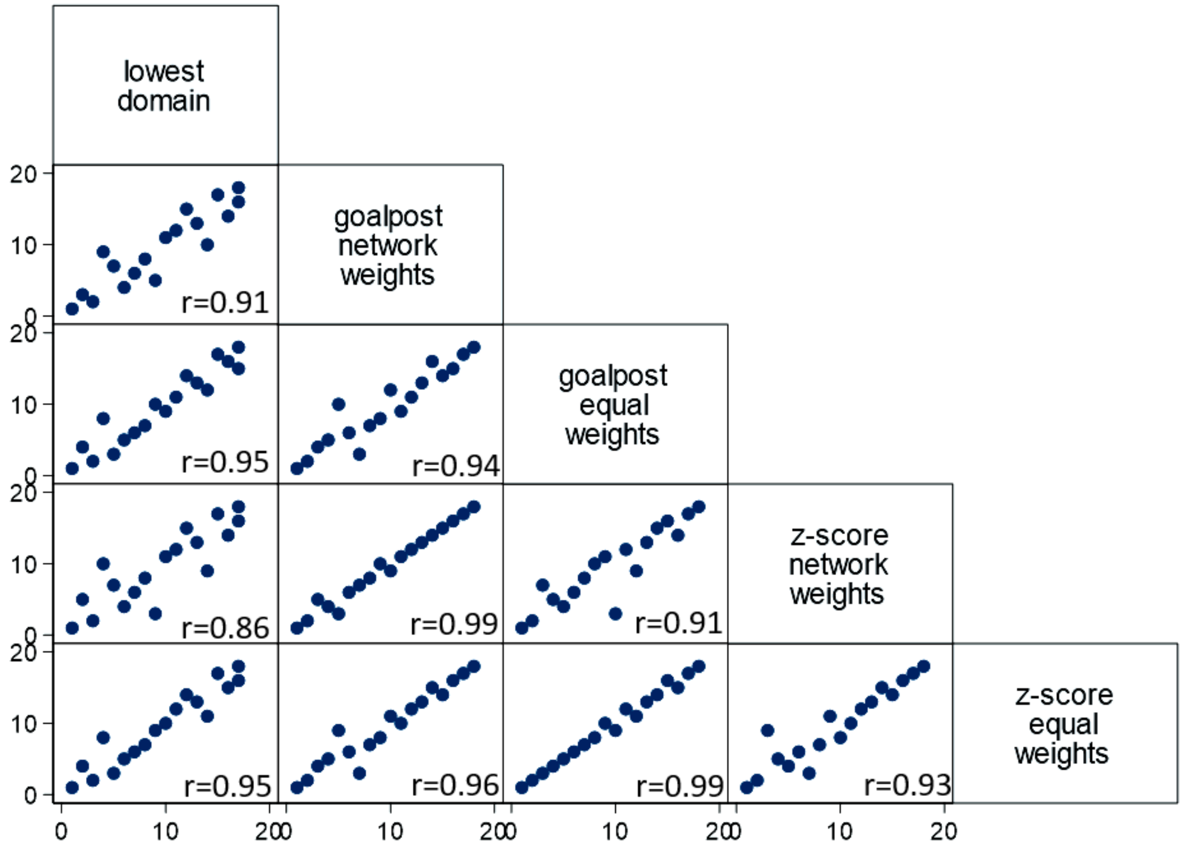
Fig. 3 and Table 3 compares countries' rankings across weighting schemes and methods for assessing progress. The rankings were highly correlated ($r_p \geq 0.86$), with Norway always coming up top and Hungary last. Using the network weights, both the goalpost and z-score methods ranked Norway, Sweden, U.S., Netherlands and Japan as the top five countries. When equal weights were used, these countries remained at the top except for Japan, being replaced by Denmark. Nevertheless, the Aging Society Index yields consistent results on rankings ($r > 0.86$) using different methods and weighting strategies.

Fig. 2. Scatterplot and correlations of scores from different computation methods and weighting strategies in Aging Society Index



r: Pearson correlation coefficient. ***Lowest domain****: minimum score over five domain so that a low score in any one domain cannot be offset by higher scores in other domains.* ***Goalpost****: all individual measures are standardized with a score of 0 for the worst performing country in the data set available and a score of 100 as the best performing countries, where higher values indicate better outcomes in the aging society.* ***Z-scores*** *method allows for the standardization of indicators of different types and scales and provided a convenient way to normalize results, by anchoring them around the mean.* ***Network weights*** *are the average weights to the measures based on the recommendations of the thirteen member Network.* ***Equal weights*** *was to weigh all measures within a domain equally with all weights summing to 100%.*

Fig. 3. Scatterplot and correlations of rankings from different computation methods and weighting strategies in Aging Society Index



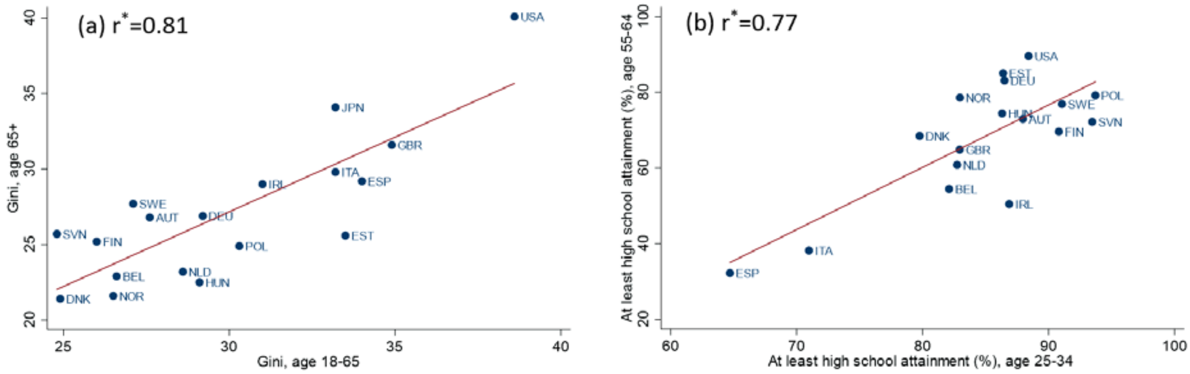
r: Pearson correlation coefficient. ***Lowest domain****: minimum score over five domain so that a low score in any one domain cannot be offset by higher scores in other domains.* ***Goalpost****: all individual measures are standardized with a score of 0 for the worst performing country in the data set available and a score of 100 as the best performing countries, where higher values indicate better outcomes in the aging society.* ***Z-scores*** *method allows for the standardization of indicators of different types and scales and provided a convenient way to normalize results, by anchoring them around the mean.* ***Network weights*** *are the average weights to the measures based on the recommendations of the thirteen member Network.* ***Equal weights*** *was to weigh all measures within a domain equally with all weights summing to 100%.*

Table 3. Countries rankings from different computation methods and weighting strategies

Country	Lowest domain	Goalpost (network weights)	Goalpost (equal weights)	Z-score (network weights)	Z-score (equal weights)
Austria	11	12	11	12	12
Belgium	13	13	13	13	13
Denmark	5	7	3	7	3
Estonia	17	16	15	16	16
Finland	4	9	8	10	8
Germany	8	8	7	8	7
Hungary	17	18	18	18	18
Ireland	7	6	6	6	6
Italy	16	14	16	14	15
Japan	9	5	10	3	9
Netherlands	6	4	5	4	5
Norway	1	1	1	1	1
Poland	15	17	17	17	17
Slovenia	12	15	14	15	14
Spain	14	10	12	9	11
Sweden	3	2	2	2	2
United Kingdom	10	11	9	11	10
United States	2	3	4	5	4

We also compared the correlation of measures available for both the young and old. In Fig. 4, we found that the Gini coefficient of the young (age 18 to 65 years) and old (age 65+) were highly correlated, similarly for high school attainment. We acknowledge the failure to capture retirement transition in our index, nevertheless the high correlation of measures between the young and old suggest that our results might be fairly robust.

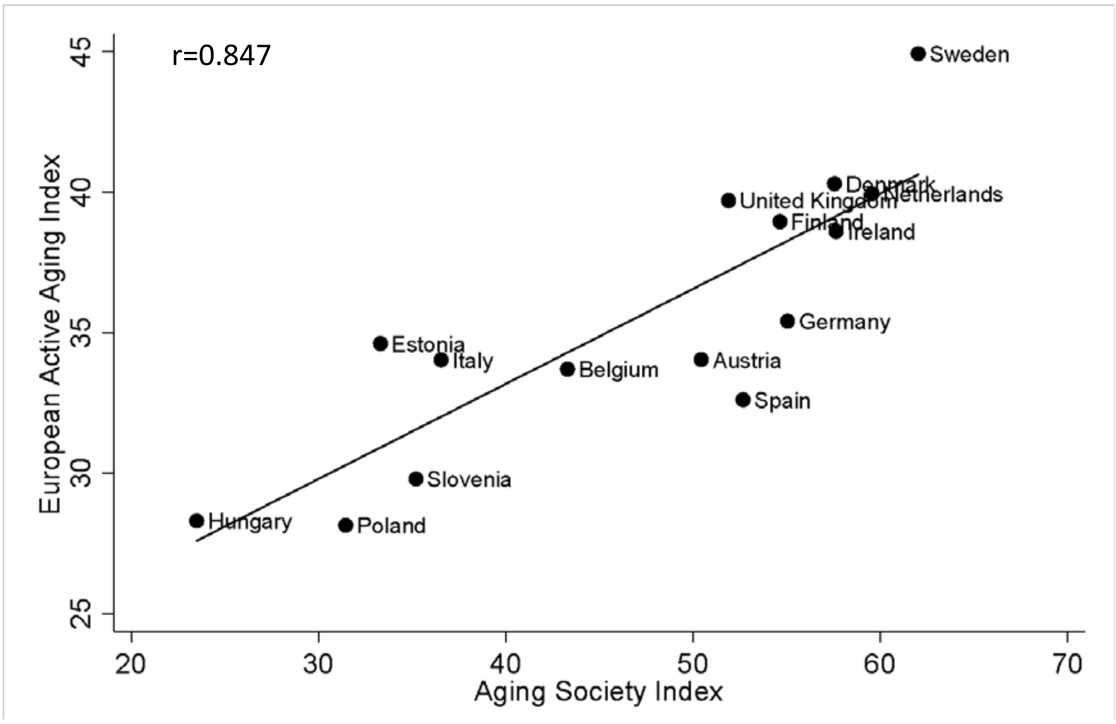
Fig. 4. Comparison of (a) Gini coefficient and (b) Education between the old and young



* *r: correlation coefficient, where each point represent one country*

We also compared the Aging Index with other index. The European Active Aging Index (AAI) is a cross-national comparison that is not available for the U.S., thus we compared using only the EU countries (Fig. 5). While there is high correlation of 0.85, we found that Sweden and Estonia are above the regression as they rank high on PRODUCTIVITY AND ENGAGEMENT domain & AAI weigh heavily this measure. Converse is true for countries below the regression (Spain, Austria, Solvenia and Poland), scoring low on AAI due to low PRODUCTIVITY AND ENGAGEMENT.

Fig. 5. Scatterplot of European Active Aging Index and Aging Society Index



6. Programs:

<u>agingindex.R</u>

```
#   This file produces the Aging index scores and rank for 18 OECD countries.
#   The input data file : country_data.csv
#   Other code files required: calculate.R, goalpost.R, zscore.R

rm(list=ls())
setwd("...")
source("calculate.R")

## Prepare data
  data    <- read.csv("country_data.csv", header = TRUE, row.names = 1)

  Domains <- list()
  Names   <- c("Productivity", "Wellbeing", "Equity", "Cohesion", "Security")
  n       <- length(Names)
  row     <- nrow(data)

  for (a in 1:n) Domains[[a]] <- data[,grep(Names[a],colnames(data))]
  names(Domains) <- Names

## Set weights

  ## individual domain constituents

  network <- list( Productivity = c(0.35,    0.2555555556,  0.2222222222,  0.1722222222),
                Wellbeing = c(0.70,  0.30),
                Equity = c(0.2959502,         0.1557632,        0.2398754,        0.1401869,        0.1682243),
                Cohesion = c(1,       0,         0,  0,     0,          0,          0),
                Security = c(0,         0.343941140899012,     0.241242088288652,
          0.098671638782504,     0.177206208425721, 0, 0.137938923604112) )

  equal   <- list( Productivity = c(0.25,      0.25, 0.25,         0.25),
                Wellbeing = c(0.50,  0.50),
                Equity = c(0.20,       0.20,      0.20,     0.20,     0.20),
                Cohesion = c(1,       0,         0,  0,     0,          0,          0),
                Security = c(0,         0.20,      0.20,     0.20,     0.20, 0, 0.20) )

  ## domain weights

  dom.network <- c(0.215, 0.245, 0.18, 0.17, 0.19)

  dom.equal   <- c(0.2, 0.2, 0.2, 0.2, 0.2)

## Calculate index

  # calculate.index(X, weight, domain_weight, zscore = FALSE, simple = TRUE, min = FALSE)
  # The function calls "goalpost.R" and "zscore.R"
  # X :: List of domains
  # weight :: List of weights for individual components in a domain;
  # length of individual list entry must match column dimension of list entry in X;
  # otherwise, an error is returned
  # domain_weight :: Vector of weights for each domain
```

```
  # zscore :: if TRUE, calculates the z-score instead of using the goalpost method
  # simple :: if TRUE, lets "Social support" fully represent "cohesion"
  # min :: if TRUE, sets the index to be the minimum of all domain scores

  # calculate.index returns a list with
  # 1) individual domain scores ( ... $ domain.sum)
  # 2) index (... $ index)

  # network weighted goalpost
  goalpost.network <- calculate.index(Domains, network, dom.network, zscore = FALSE, simple =
TRUE, min = FALSE) $ index

  # equal weighted goalpost
  goalpost.equal   <- calculate.index(Domains, equal, dom.equal, zscore = FALSE, simple = TRUE,
min = FALSE) $ index

  # network weighted zscore
  zscore.network   <- calculate.index(Domains, network, dom.network, zscore = TRUE, simple =
TRUE, min = FALSE) $ index

  # equal weighted zscore
  zscore.equal     <- calculate.index(Domains, equal, dom.equal, zscore = TRUE, simple = TRUE, min
= FALSE) $ index

  # lowest domain
  goalpost.min     <- calculate.index(Domains, network, dom.network, zscore = FALSE, simple =
TRUE, min = TRUE) $ index

## Produce figures and tables

  lower.panel <- function(x,y) {
      #par(xaxt = "n", yaxt = "n")
      points(x,y, pch=19, col="navy")
      corr <- round(cor(x,y), digits = 3)
      txt <- paste0("R = ", corr)
      usr  <- par("usr"); on.exit(par(usr))
      par(usr = c(0,1,0,1))
      text(0.8, 0.2, txt)
  }

  ## Produce correlogram between for the alternative indices

  table <- cbind(goalpost.min,goalpost.network,goalpost.equal,zscore.network,zscore.equal)
  colnames(table) <- c("lowest\ndomain", "goalpost\nnetwork\nweights",
                    "goalpost\nequal\nweights", "z-score\nnetwork\nweights",
                    "z-score\nequal\nweights")
  table.p <- table
  table.p[,c(4,5)] <- pnorm(table.p[,c(4,5)])*100

  pairs(table.p, upper.panel = NULL , lower.panel = lower.panel, cex.labels = 1.2)

  ## Produce correlogram for the alternative rankings

  ranktable <- cbind( round(rank(-goalpost.min, ties.method = "min"),0), rank(-goalpost.network),
                rank(-goalpost.equal), rank(-zscore.network),
                rank(-zscore.equal))
```

```
colnames(ranktable) <- c("lowest\ndomain", "goalpost\nnetwork\nweights",
                 "goalpost\nequal\nweights", "z-score\nnetwork\nweights",
                 "z-score\nequal\nweights")

pairs(ranktable, upper.panel = NULL , lower.panel = lower.panel, cex.labels = 1.2)
```

calculate.R

```
#   Aging Index : calculate index

  calculate.index <- function(X2, weight2, dom.weight, zscore = FALSE, simple = TRUE, min = FALSE)
{

    source("goalpost.R")
    source("zscore.R")

    row <- nrow(X2[[1]][1])
    n   <- length(X2)

    if (simple == TRUE) {

      weight2[["Cohesion"]] <- c(1, rep(0,length(weight2$Cohesion)-1))

    } else weight2[["Cohesion"]][1] <- 0.34482759

    domain.sum <- matrix(0, row, n)
    index      <- 0

    if (zscore == FALSE) {

      for (b in 1:n) {
        domain.sum[,b] <- Goalpost(X2[[b]],weight2[[b]])
        colnames(domain.sum) <- names(X2)
        index <- domain.sum[,b] * dom.weight[b] + index
      }

    } else {
      for (b in 1:n) {
        domain.sum[,b] <- zscore(X2[[b]],weight2[[b]])
        colnames(domain.sum) <- names(X2)
        index <- domain.sum[,b] * dom.weight[b] + index
      }
    }

    if (min == TRUE) for (d in 1:row) index[d] <- min(domain.sum[d,])

    if (simple == FALSE) {
      row.index <- which(is.na(X2[["Cohesion"]]), arr.ind= TRUE)[,1]
      index[row.index] <- NA
      domain.sum[,"Cohesion"][row.index] <- NA
    }

    row.names(domain.sum) <- row.names(X2[[1]])
    names(index) <- row.names(X2[[1]])
    return(list(domain.sum = domain.sum, index = index))

  }
```

goalpost.R

```
# Aging Index : Goal post

 Goalpost <- function(X, weight) {

   m <- ncol(X);

       if (length(weight) != m) {
         message("Dimensions of weights not equal to number of variables in domain")
         break
       }

   mm <- nrow(X)
   domain.sum <- rep(0, mm)

     for (b in 1:m) {
       min <- min(na.omit(X[,b])); max <- max(na.omit(X[,b]));
       X[,b][is.na(X[,b])] <- 0
       for (c in 1:mm) {
       domain.sum[c] <- domain.sum[c] + weight[b] * ((X[c,b] - min)/(max - min) * 100)
       }
     }

   return(domain.sum)
 }
```

zscore.R

```
#   Aging Index : Z score

  zscore <- function(X, weight) {

    m <- ncol(X);

        if (length(weight) != m) {
          message("Dimensions of weights not equal to number of variables in domain")
          break
        }

    mm <- nrow(X)
    domain.sum <- rep(0, mm)

      for (b in 1:m) {
        avg <- mean(na.omit(X[,b])); sd <- sd(na.omit(X[,b]));
        X[,b][is.na(X[,b])] <- 0
        for (c in 1:mm) {
        domain.sum[c] <- domain.sum[c] + weight[b] * ((X[c,b] - avg)/sd)
        }
      }

    return(domain.sum)
  }
```

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