2 MODELLING GENERATIONAL CHANGES: USA AS A STUDY CASE

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Abstract

The economy is functioning under the simultaneous participation of the coexistent generations in production of goods and services, saving-investment processes, private and public consumption, domestic and foreign trade, research-development of the new products and technologies, and all the other inter-connected economic activities. This complex role of generations can be examined from two perspectives: i) as income relevance, estimated by the shares of the coexistent generations in forming or utilization of disposable revenues; and ii) as socio-economic functional status of its members (wealth property structure, positions held in the micro- and macroeconomic management etc.). The present paper concentrates on the former. The empirical search will be focused on the historical experience of the United States of America, for which there already is available a consistent set of connected sociological studies, as well as exhaustive statistical information.

Keywords: demographic structure, generation, income generational relevance

JEL Codes: C82, J11, J17

1. Introduction

1. The last decades have projected the generational issue as one of the leading socio-economic research trends. A massive body of literature has been devoted to the conceptual roots and qualitative co-ordinates of this category (Mannheim 1927/1928 - republished 1952, Bourdieu 1977, Wohl 1979, Schuman and Scott 1989, Strauss and Howe 1991, Pilcher 1994, Dionne 1995, Eyerman and Turner 1998, The Myth of Generational Conflict 2000, Grenier 2007, Bourcier-Béquaert and de Barnier 2010, Timonen and Conlon 2015, Jureit 2017). In principle (Pilcher 1994, Timonen and Conlon 2014, Jureit 2017, Cardenas 2022, OECD: Glossary), a generation is considered as a group of persons characterized by a common forming demographic pattern, respectively who lived in similar familial environments and school systems, and faced analogous economic, political, geo-strategical, natural, sanitary, or culture-shifting historical events. It seems reasonable to admit that demographic cohorts belonging to such an interval – close enough in terms of education and life experience (in the broadest sociological sense) – are also close from a behavioral standpoint.

2. A generation span is usually approximated depending on the demographic reproductive cycle. In the case of females, for example, across OECD countries the average age at which women give birth to a first child is 27, whereas in Korea it is as high as 31.6 (OECD: Glossary); according to other works, the average female line lineages at 28-29 years (Hutton 2022) or only 23.8 years (Fenner 2005). For the males, there were advanced estimations such as 27.3 years (Fenner

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2005), 30.7 years (Wang *et al.* 2021), around 31-32 (Hutton 2022). Should the family unit be used as a criterion, the average of 25 years from the birth of a parent to the birth of a child (Devine 2005) is admitted as a generation span. Some authors formulated this issue in general:

- 'a mean value of 30 years is a better estimate of intergenerational intervals than 20 or 25 years' (Tremblay and Vézina 2000);
- '3.5 generations per century, i.e. an average generation length of 29 years' (ISOGG 2015);
- 'around 20 years in length, but some suggest longer periods – up to 30 years' (Ruthven 2018);
- 'most research centers agree a generation is anywhere between 20 and 30 years' (Tetrault 2021);
- 'an average generation time of 26.9 years across the past 250,000 years' (Wang *et al.* 2021);
- 'how long is a human generation?, short answer 25 years, but a generation ago it was 20 years' (Laden 2022);
- Frequently, there was revealed a great variety of possible generations' types (Safire 2008, Dimock 2019).

3. This diversity of generational span estimations indicates, in our opinion, the difficulty (if not the impossibility) to identify a singular, atemporal benchmark in establishing the generation span. From this point of view, the attempts to use the shared apprehension by the given group of a certain exceptional historical event appear to be more promising. (Shamma 2011, Desjardins 2021. Ghosh *et al.* 2021, Taner 2022). Pew Research Center (2016) listed the following events as most cited by the representatives of different American generations: 2001 September 11; Obama election/presidency; the Tech Revolution'; JFK assassination; Vietnam War; Moon landing; Iraq/Afghanistan wars; Gay marriage; Orlando/Pulse shooting' Gulf War.

4. Since, over time, the life expectancy surpasses – in an increasing proportion even – the generational reproductive cycle, society is constantly composed of several generations, labelled as coexistent. During the past one and a half centuries, a massive body of literature (Strauss and Howe 1991, Statistics Canada 2011, Eastman and Liu 2012, Parment 2013, Moss 2017, Fry 2020, Klubes 2020, Morton 2020, Tetrault 2021, Cardenas 2022, Hutton 2022, The Free Encyclopedia 2022, Laden 2022) has embraced for the modern Western world, especially the American one, the following classification:

- Lost Generation – L (individuals born between 1883 and 1900);
- Greatest Generation – G (born from 1901 to 1927);
- Silent Generation – S (born from 1928 to 1945);
- Baby boomers - B (born from 1946 to 1964);
- Generation - X (born between 1965 and 1980);
- Millennials, also known as Generation - Y (early 1980s as starting and 1990s as ending birth years);
- Generation 'Zoomers' – Z (mid-to-late 1990s as starting and the early 2010s as ending birth years); last year, there was elected first Gen Z member of U. S. Congress (Liu 2022);
- Generation Alpha – A (early 2010s as starting and 2020s as ending birth years). It seems more plausible to prolong duration of this generation until 2030, and to add one new:
- Beta generation – B (2030-2050).

Since our intention is to cover an as long as possible historical period, this formation will be completed with a Pre-lost Generation – pL (before 1880). Our empirical analysis will involve, therefore, ten different generations.

Surely, these demarcations are relative (Cohen 2021), intersecting with other studies about the peculiarities of the different population segments, such as those regarding marketing (Rentz and Reynolds 1991, Fitzgerald Bone 1991, Mueller-Heuman, 1992, Down and Reveley 2004, Schewe and Meredith 2004, Folkman Curasi *et al.* 2004, Fukuda 2009, Chaney *et al.* 2017), the workforce diversity (Parry and Urwin 2011), the functioning of organizations (Joshi *et al.* 2010), and, last but not least, the remarkable research on the link between the intergenerational mobility and the support for redistributive policies (Alesina *et al.* 2018). Such, and many other similar conceptual connections outline the prominent position played by the generational theory in the modern socio-economic analysis.

5. Hereinafter, the paper proposes an algorithm simulating the dynamics of the generational structure of society. According to its main methodological premise, all the coexistent generations evolve with the same surviving rates, established for 101 age-groups of people. This obviously simplifying assumption was chosen for an increased tractability of the model.

The third chapter of the paper introduces the so called `income generational relevance`, based on the assumption that the economic role of a generation is more accentuated during the youth and maturity of its members, decreasing gradually with the ageing process. Correspondingly, this means that the personal income should register a nonlinear dynamic in dependence on the age group, describing an inverted U-curve (parabola with maxim). In the case of USA, the income-age rating (IAR_k) is defined by the average income of the age-group k normalized by min-max procedures.

The correspondingly derived income-age scale is applied identically to all the coexistent generations. This assumption is in line with the general principles of the democratic systems, consisting into the absence of any discriminating role of the generational belongingness. This concerns, of course, any kind of personal incomes, regardless of their sources (labor, wealth, public funds etc.). The individual income for a given age group does not, therefore, differ significantly in dependence on the generation to which the various individuals belong. The income generational relevance (IGR_{jt}) summarizes the income-age ratings of all the inhabitants belonging to the generation j in year t.

2. Algorithm for simulating the demographic structures

2.A. General scheme

The generational evolution is going to be simulated by a simple algorithm of the structural demographic changes. The main variables involved in this algorithm are:

- *t* – time, referring to the entire considered historical interval (*t=1, 2,.., T*);
- *i* – the age-group of population; *i = 1, 2,…, 101*; the first age-group is named “the one-year children' (UYC);
- *j* – symbol of the generations; *j=pL, L, G, S, B, X, Y, Z, A, B*;
- BSR_i – basic surviving rate of age-group *i*, comparatively with *UYC*;
- coh_{it} – number of inhabitants of age-group *i* in year *t*; $coh_{it}=BSR_i*UYC_{t-i+1}$;
- coh_j - number of inhabitants belonging to generation *j*; $coh_j=\sum POP_j$, in which *j* includes all the years of the respective generation.
- POP_t – total population (number of inhabitants of the all age-groups in year t).

The main operational relationship of the proposed algorithm is:

$$POP_t=UYC_{t-100}*BSR_{101}+UYC_{t-99}*BSR_{100}+UYC_{t-98}*BSR_{99}+...+UYC_{t-1}*BSR_2+UYC_t*BSR_1 \qquad (1)$$

As an empirical application, this algorithm is executed on the time span 1980 - 2050, computations for such an interval requiring data starting with the 1880s. Some technical problems raised by the necessary composing data base are examined in subchapters IIB. ‘Basic surviving rates (BSR)’ and IIC. ‘Approximation of the UYC (‘under one-year children’)’.

2.B. Basic surviving rates (BSR)

1. Yearly change of the generation size depends essentially on the probability of dying between consecutive ages (q_i). Table 1 presents such a series with reference to entire population.

Table 1. Probability of dying between consecutive ages, total population 2018

Age-group (years)	q_i	Age-group (years)	q_i	Age-group (years)	q_i	Age (years)	q_i	Age (years)	q_i
1	0.00565	21	0.00075	41	0.00193	61	0.009109	81	0.047201
2	0.00037	22	0.000837	42	0.00202	62	0.009795	82	0.052599
3	0.00026	23	0.000915	43	0.002139	63	0.010492	83	0.058586
4	0.00019	24	0.000978	44	0.002289	64	0.011192	84	0.065124
5	0.00015	25	0.001029	45	0.002462	65	0.011915	85	0.0734
6	0.00014	26	0.001075	46	0.002654	66	0.012691	86	0.081636
7	0.00013	27	0.00112	47	0.002863	67	0.01361	87	0.089815
8	0.00011	28	0.001164	48	0.003091	68	0.014606	88	0.100898
9	0.00010	29	0.001209	49	0.003347	69	0.015724	89	0.113081
10	0.00009	30	0.001256	50	0.003638	70	0.017004	90	0.126406
11	0.00009	31	0.001306	51	0.00395	71	0.018391	91	0.140901
12	0.00010	32	0.001357	52	0.004297	72	0.019831	92	0.156577
13	0.00013	33	0.001414	53	0.004709	73	0.021913	93	0.173422
14	0.00018	34	0.001475	54	0.005186	74	0.023804	94	0.191399
15	0.00025	35	0.001538	55	0.005701	75	0.026193	95	0.210444
16	0.00033	36	0.00161	56	0.006223	76	0.028692	96	0.230465
17	0.00041	37	0.001686	57	0.006744	77	0.031786	97	0.251342
18	0.00049	38	0.001753	58	0.007281	78	0.035136	98	0.272927
19	0.00058	39	0.001809	59	0.007848	79	0.038673	99	0.295049
20	0.00066	40	0.001864	60	0.008454	80	0.042747	100	0.317517
								100 and over	1

2. These series are transformed into basic surviving rates (BSR_i) through:

$$BSR_i=BSR_{(i-1)}*(1-q(i-1)) \tag{2}$$

In principle, the hypothesis of the differentiated by generations of BSR cannot be excluded. For the moment, however, we have not identified adequate information~~al~~ sources for its plausible estimation. Consequently, there was adopted a unique BSR series for all generations.

2.C. Approximation of the UYC

1. Compounding the series of 'under one-year children (*UYC1*)' required consulting many sources, among which: 1880 Census, 1900 Census, 1910 Census, Zelnik 1961, U.S. Census Bureau 2004, U.S. Census 2021, Openstax 2022, Federal Reserve Bank of St. Louis 2022, US Population by Year 2022, World Bank 2022. Since our goal was to compare as many coexistent generations as possible, we tried to cover the time span 1880 – 2050 by combining statistical data with predictive ones. Appendix Ap1 synthetizes the series pertaining to the total population (*POP*) and the population of 01-14 years (*POP01_14*); the share of the age-group of 0 - 14 years in the population total (*rPOP01_ 14*) is also specified.

2. An attempt to compose a primary series of 'under one-year children' has proven to be very difficult. Consequently, there was adopted an indirect way, starting from identity *UYC=rPOP01*POP*, where *rPOP01* is the share of the 'under one-year children' in the population total. The main computational steps are the following:

2.1. Initially, the number of 'under one-year children' is estimated as a preliminary value (noted *UYCP*). This corresponds to the assumption that the share of 'under one-year children' in the population total is deducible from the similar rate concerning the age-group of 0 - 14 years (*rPOP01_14*), amended by an exogenous corrective coefficient $ɯ$:

$$UYCPɯ=(r14/\sum BSRh)*ɯ*POP\ (h=1, 2, ..., 14) \tag{3}$$

In our application, $\sum BSR_h \approx 13.912$. For clarity purposes, it is assumed *BSR* remains constant for the entire sample. The corrective coefficient $ɯ$ is chosen from a series of m successive positive values: in our case, we opted for $m=21$, $ɯ=1, 1.01, 1.02,..., 1.2$, respectively.

2.2. Based on this, we estimated the corresponding preliminary total population ($POPP_t$):

$$POPPt=UYCPɯ(t-100)*BSR101+UYCPɯ(t-99)*BSR100+UYCPɯ(t-98)*BSR99+...+ UYCPɯ(t-1)*BSR2+UYCP\ ɯt*BSR1 \tag{4}$$

$$\begin{aligned} POPPɯt = &((r14/\sum BSRh)*ɯ)*POP(t-100)*BSR101+((r14/\sum BSRh)*ɯ)* \\ &*POP(t-99)*BSR100 +((r14/\sum BSRh)*ɯ)*POP(t-98)*BSR99+...+((r14/\sum BSRh)*ɯ)* \\ &*POP\ t-1*BSR2+((r14/\sum BSRh)*ɯ)*POPt*BSR1 =((r14/\sum BSRh)*ɯ)* \\ &*(POP(t-100)*BSR101+POP(t-99)*BSR100+POP(t-98)*BSR99+...+ \\ &+POP(t-1)*BSR2+POPt*BSR1) \end{aligned} \tag{4a}$$

For the preliminary total of population computed in this manner (21 variants of $ɯ$), we determined the squared relative deviations against the reference data (d^2POP_t):

$$d2POPɯt=(POPPɯt/POPt-1)^2 \tag{5}$$

of which the sum for the entire sample (DPOP) is:

$$DPOP=\sum d2POPɯt \qquad (t=1, 2,.., n) \tag{6}$$

2.3. For the model estimation (*POPM*) we selected the corrective coefficient which minimizes *DPOP* (noted $ɯ_@$):

$$POPM_t=((r14/\sum BSR_h)*ɯ_@)*(POP_{(t-100)}*BSR_{101}+POP_{(t-99)}*BSR_{100} + POP_{(t-98)}*BSR_{99}+...+POP_{(t-1)}*BSR_2+POP_t*BSR_1) \tag{7}$$

3. For the time span 1900 - 2021, the share of age-group under 14 years in the total population is displayed in Appendix Ap1. Aiming to work with a more pertinent database, this paper attempts - by means of forward (2022 - 2050) and backward (1880 - 1899) econometric estimations - to

create a continuous series 1880 - 2050. To this end, the available data for the years 1900 to 2021 were treated as an auto-regressive process.

Regarding the time span 2022 - 2050, a customary VAR model has been considered a proper solution, since a subsequent extrapolative operation is involved. Because of the opposing ‘arrow of time’, we have admitted that similar approximations for the years 1880 to 1899 could be rather obtained by applying VAR technique on conversely ordered disposable series. Conventionally, the first approach was called the ‘direct’ VAR (noted VAR1), and the second one - the ‘reverse’ VAR (VAR2). The lag selection length is governed by both the informational criteria (the corresponding applications are identified by suffix a), and the R-squared scores (suffix b).

4. Concerning the direct VAR, two specifications were retained:

4.1. The informational criteria are presented in Table 2a.

Table 2a. VAR1 lag order selection information criteria

Lag	FPE: Final prediction error	AIC: Akaike information criterion	SC: Schwarz information criterion	HQ: Hannan-Quinn information criterion
0	0.001237	-3.857407	-3.830864	-3.846675
1	0.000016	-8.219220	-8.166133	-8.197754
2	0.000012	-8.526026	-8.446396	-8.493828
3	0.000009	-8.787938	-8.681764	-8.745006
4	0.000008	-8.889713	-8.756996*	-8.836048
5	0.000008	-8.874633	-8.715372	-8.810235
6	0.000008	-8.872170	-8.686366	-8.797040
7	0.000008	-8.852710	-8.640363	-8.766847
8	0.000008	-8.839935	-8.601045	-8.743340
9	0.000008	-8.858236	-8.592802	-8.750908
10	0.000008	-8.866472	-8.574495	-8.748411
11	0.000008	-8.898461	-8.579940	-8.769667
12	0.000008	-8.898359	-8.553295	-8.758832
13	0.000007	-9.069171	-8.697564	-8.918911
14	0.000007	-9.081077	-8.682926	-8.920085*
15	0.000007	-9.075230	-8.650535	-8.903504
16	0.00000659*	-9.095989*	-8.644751	-8.913530
17	0.000007	-9.075515	-8.597733	-8.882323
18	0.000007	-9.056249	-8.551924	-8.852325
19	0.000007	-9.042426	-8.511558	-8.827769
20	0.000007	-9.054884	-8.497473	-8.829494
21	0.000007	-9.035489	-8.451534	-8.799366
22	0.000007	-9.020390	-8.409892	-8.773535
23	0.000007	-9.017084	-8.380042	-8.759495
24	0.000007	-8.996480	-8.332895	-8.728159
25	0.000007	-9.033703	-8.343574	-8.754648

*Note: * indicates lag order selected by the criterion*

Hence, both the final prediction error and the Akaike information criterion suggest 16 lags as optimal; the Schwarz information criterion points to four, and the Hannan-Quinn one - to 14. Reflecting a considerable part of the available database, the level indicated by the first two tests, which is 16 lags, was retained for computing the model VAR1a:

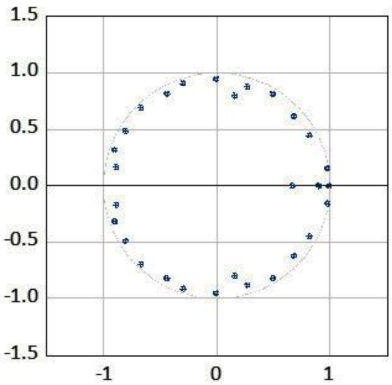
$$
\begin{aligned}
rPOP01\_14 = {} & 0.874105*rPOP01\_14(-1) + 0.327210*rPOP01\_14(-2) \\
& + .010919*rPOP01\_14(-3) - 0.025858*rPOP01\_14(-4) - 0.030186*rPOP01\_14(-5) \\
& + 0.296754*rPOP01\_14(-6) - 0.530011*rPOP01\_14(-7) - 0.074972*rPOP01\_14(-8) \\
& + 0.096437*rPOP01\_14(-9) - 0.017312*rPOP01\_14(-10)
\end{aligned}
$$

$$+ 0.060803*rPOP01\_14(-11) - 0.266685*rPOP01\_14(-12)$$
$$+ 0.390930*rPOP01\_14(-13) - 0.167344*rPOP01\_14(-14)$$
$$- 0.104419*rPOP01\_14(-15) + 0.149840*rPOP01\_14(-16) + 0.001778 \quad (8)$$

The coefficient of determination is 0.994724. Since the goal of this exercise is only to approximate some missing data, a comprehensive testing of the regression accuracy is not considered relevant.

4.2. From the R-squared perspective, the longest possible VAR should be preferred – surely, without violating the unit root condition. This approach was sometimes called (Dobrescu 2020, 2022) 'the longest stable VAR' (LsVAR). In case of the series 1900 - 2021, such a VAR contains 29 lags. Figure 1 displays the inverse roots of the characteristic polynomials of VAR1b.

Figure 1. Inverse roots of the characteristic polynomials of VAR1b



The corresponding model is:

$$rPOP01\_14 = 1.274551*rPOP01\_14(-1) - 0.202496*rPOP01\_14(-2)$$
$$+ 0.121467*rPOP01\_14(-3) - 0.056709*rPOP01\_14(-4) + 0.136700*rPOP01\_14(-5)$$
$$- 0.335329*rPOP01\_14(-6) + 0.230163*rPOP01\_14(-7) - 0.421129*rPOP01\_14(-8)$$
$$+ 0.393653*rPOP01\_14(-9) - 0.259080*rPOP01\_14(-10) + 0.215061*rPOP01\_14(-11)$$
$$- 0.230096*rPOP01\_14(-12) + 0.285357*rPOP01\_14(-13) - 0.381928*rPOP01\_14(-14)$$
$$+ 0.140695*rPOP01\_14(-15) + 0.066608*rPOP01\_14(-16) + 0.003527*rPOP01\_14(-17)$$
$$- 0.112777*rPOP01\_14(-18) + 0.263074*rPOP01\_14(-19) - 0.188978*rPOP01\_14(-20)$$
$$+ 0.048006*rPOP01\_14(-21) - 0.064391*rPOP01\_14(-22) + 0.078945*rPOP01\_14(-23)$$
$$+ 0.154158*rPOP01\_14(-24) - 0.133208*rPOP01\_14(-25) - 0.058616*rPOP01\_14(-26)$$
$$+ 0.147789*rPOP01\_14(-27) - 0.212980*rPOP01\_14(-28) + 0.095917*rPOP01\_14(-29)$$
$$+ 0.000186 \quad (9)$$

with the R-squared = 0.996988.

Based on the models VAR1a and VAR1b we approximated the missing data for the time span 2022 - 2050.

5. An identical solution was adopted for the inverted series 1900 - 2021.

5.1. The informational criteria display as follows:

Table 2b. VAR2 lag order selection information criteria

Lag	FPE: Final prediction error	AIC: Akaike information criterion	SC: Schwarz information criterion	HQ: Hannan-Quinn information criterion
0	0.001161	-3.92063	-3.89409	-3.9099
1	2.65E-05	-7.6998	-7.64672	-7.67834
2	2.67E-05	-7.69359	-7.61396	-7.66139
3	2.32E-05	-7.83277	-7.72659	-7.78984
4	2.05E-05	-7.95672	-7.82401	-7.90306
5	1.98E-05	-7.99022	-7.83096	-7.92582
6	2.02E-05	-7.97223	-7.78643	-7.8971
7	1.89E-05	-8.03939	-7.82704	-7.95353
8	1.92E-05	-8.02279	-7.78389	-7.92619
9	1.87E-05	-8.0525	-7.78707	-7.94518
10	1.84E-05	-8.06888	-7.77691	-7.95082
11	1.82E-05	-8.07486	-7.75634	-7.94606
12	1.86E-05	-8.05541	-7.71035	-7.91588
13	1.58e-05*	-8.217247*	-7.845639*	-8.066987*
14	1.59E-05	-8.21432	-7.81617	-8.05332
15	1.62E-05	-8.19406	-7.76937	-8.02234
16	0.000016	-8.20564	-7.7544	-8.02318
17	1.64E-05	-8.18504	-7.70726	-7.99185
18	1.67E-05	-8.17009	-7.66576	-7.96616
19	0.000017	-8.15206	-7.62119	-7.9374
20	0.000017	-8.15152	-7.59411	-7.92613
21	1.73E-05	-8.13397	-7.55002	-7.89785
22	1.75E-05	-8.12484	-7.51434	-7.87798
23	1.76E-05	-8.12292	-7.48588	-7.86533
24	1.79E-05	-8.10233	-7.43875	-7.83401
25	1.73E-05	-8.13955	-7.44943	-7.8605

This time all four tests recommend 13 lags, with the corresponding specification (VAR2a)

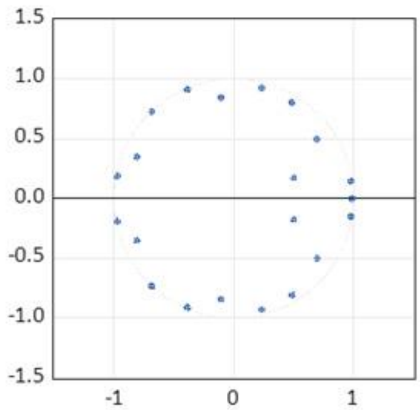
*rPOP01_14_INV = 0.864557*rPOP01_14_INV(-1) + 0.293870*rPOP01_14_INV(-2)*
*- 0.003381*rPOP01_14_INV(-3) + 0.079150*rPOP01_14_INV(-4)*
*- 0.146893*rPOP01_14_INV(-5) + 0.410762*rPOP01_14_INV(-6)*
*- 0.526590*rPOP01_14_INV(-7) - 0.201956*rPOP01_14_INV(-8)*
*+ 0.321538*rPOP01_14_INV(-9) - 0.176345*rPOP01_14_INV(-10)*
*+ 0.123830*rPOP01_14_INV(-11) - 0.327871*rPOP01_14_INV(-12)*
*+ 0.447577*rPOP01_14_INV(-13) - 0.183166*rPOP01_14_INV(-14)*
*- 0.233841*rPOP01_14_INV(-15) + 0.282250*rPOP01_14_INV(-16)*
*- 0.144802*rPOP01_14_INV(-17) + 0.039123*rPOP01_14_INV(-18)*

$$+ 0.196500*rPOP01\_14\_INV(-19) - 0.236875*rPOP01\_14\_INV(-20)$$
$$+ 0.230258*rPOP01\_14\_INV(-21) - 0.386385*rPOP01\_14\_INV(-22)$$
$$+ 0.199786*rPOP01\_14\_INV(-23) + 0.439523*rPOP01\_14\_INV(-24)$$
$$- 0.370707*rPOP01\_14\_INV(-25) + 0.003194 \qquad (10)$$

with R-squared of 0.991212.

5.2. The longest stable VAR comprises, in case of the $rpop01\_14\_inv$ series, 21 lags (VAR2b). The inverse roots of the characteristic polynomials are plotted in Figure 2.

Figure 2. Inverse roots of the characteristic polynomials of VAR2b

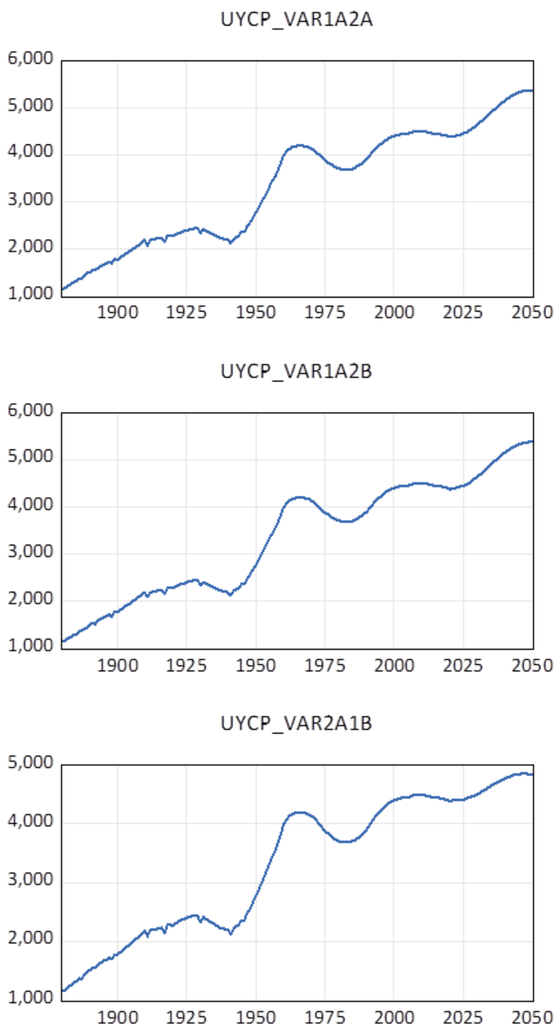


The resulted model is:

$$rPOP01\_14\_INV = 0.844844*rPOP01\_14\_INV(-1) + 0.300366*rPOP01\_14\_INV(-2)$$
$$+ 0.005725*rPOP01\_14\_INV(-3) + 0.077033*rPOP01\_14\_INV(-4)$$
$$- 0.077283*rPOP01\_14\_INV(-5) + 0.314665442343*rPOP01\_14\_INV(-6)$$
$$- 0.485731*rPOP01\_14\_INV(-7) - 0.168911*rPOP01\_14\_INV(-8)$$
$$+ 0.172830*rPOP01\_14\_INV(-9) - 0.066860*rPOP01\_14\_INV(-10)$$
$$+ 0.126868*rPOP01\_14\_INV(-11) - 0.395777*rPOP01\_14\_INV(-12)$$
$$+ 0.538041*rPOP01\_14\_INV(-13) - 0.226594*rPOP01\_14\_INV(-14)$$
$$- 0.180227*rPOP01\_14\_INV(-15) + 0.199258*rPOP01\_14\_INV(-16)$$
$$- 0.107618*rPOP01\_14\_INV(-17) + 0.042499*rPOP01\_14\_INV(-18)$$
$$+ 0.295891*rPOP01\_14\_INV(-19) - 0.300839*rPOP01\_14\_INV(-20)$$
$$+ 0.083169*rPOP01\_14\_INV(-21) + 0.002991 \qquad (11)$$

For a R-squared of 0.991120.

Figure 3a. Preliminary 'under one-year children', under ω=1 - UYCP (thousand people).



Based on the models VAR2a and VAR2b, we approximated the missing data for the time span 1880 - 1899.

5.3. The previously developed determinations of *rPOP01_14* can be combined into three distinct variants of entire series 1880-2050, identified by *r14* with suffixes of the corresponding included components: *r14_VAR1a2a*, *r14_VAR1a2b*, and *r14_VAR2a1b*. The Appendix AP2 contains the yielded numerical series.

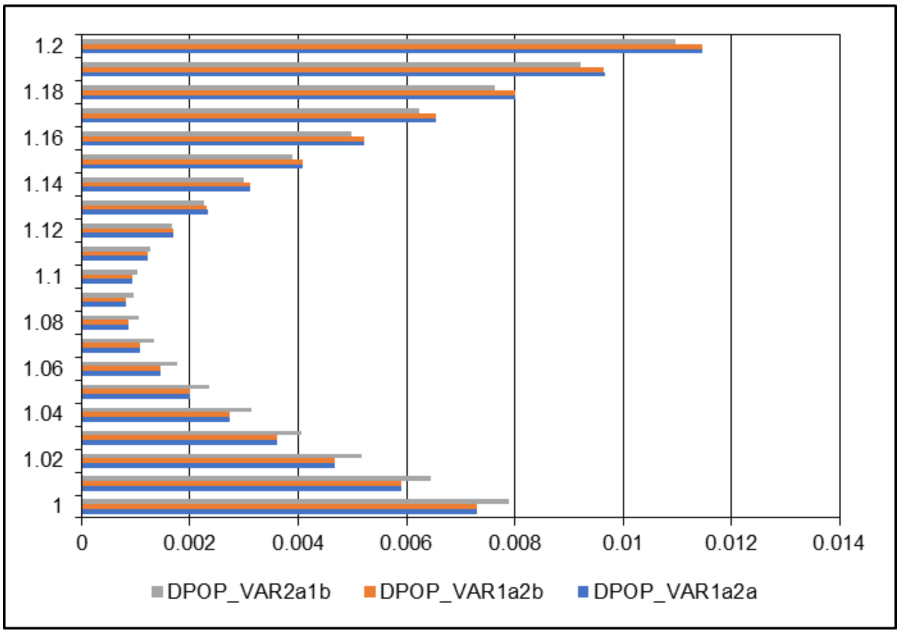
6. For these three VAR *r14,* there were computed – using the relationship (3) under ω=1 – the preliminary 'under one-year children' in thousand people (*UYCP*). The results thus obtained are sketched in Figure 3a.

With a similar slope, the estimations of $UCYP$ under $ш$=1 are, however, slightly differentiated.

Simulated for the entire adopted series $ш$ (1, 1.01, 1.02, …, 1.2), the estimations of $UCYP$ were used for determining the corresponding preliminary total population ($POPP$), and the squared relative deviations against the reference data ($DPOP$). Further details are presented in Appendix Ap3.

The variation of these deviations for compared VAR variants ($DPOP\_VAR1a2a$, $DPOP\_VAR1a2b$, and $DPOP\_VAR2a1b$), depending on changes in the corrective coefficient $ш$, is represented in Figure 3b.

Figure 3b. Variation of DPOP for compared VAR variants depending on the corrective coefficient $ш$



The minimum $DPOP$ is reached, therefore, in the case of VAR1a2b for $ш$=1.09, which will be adopted as model level ($ш$@).

3. Income generational relevance (IGR)

The economic role of the coexistent generations can be approached from many viewpoints. Two, however, are crucial: i) their impact on the forming and utilization of current outcomes of the economic activity; and ii) their positions in the institutional mechanism of managing the entire wealth of society (property structure, central and local governance, etc.). Our research is focused on the first of these perspectives.

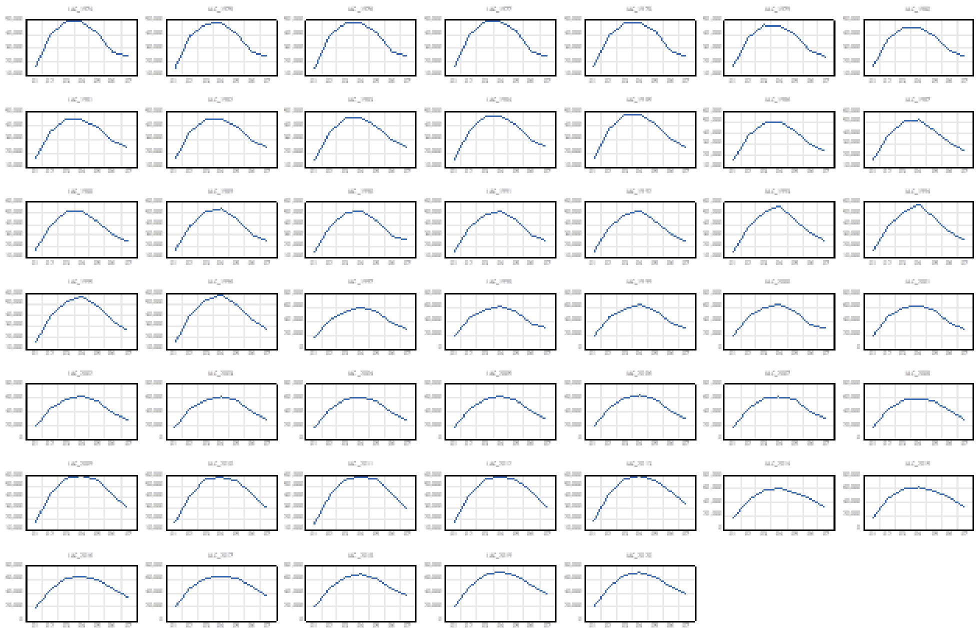
1. The relationship of income with age was extendedly analyzed in the theory of 'human life value' (Hofflander 1966, Thaler and Rosen 1976, Anderson 1993, Blomquist 2001, Kip Viscusi 2004, Sunstein *2004,* Hall and Jones 2007, Hultkrantz and Svensson 2012, Rohles *et al.* 2015, Horecký 2016, Majumder and Madheswaran 2018, Australian Government – Office of Best Practice

Regulation 2021, Carneades 2022), which emphasizes the tradeoff between wages and fatality risks, already pointed out by the classical economic school. It is worth noticing that empirical studies inspired by this mainstream identified a U inverted dependence of the income on the age (Hofflander1965, Rice and Cooper 1967, Kip Viscusi 2005, Ara and Tekeşin 2017, Routley 2018, Bureau of Labor Statistics - U.S. Department of Labor 2021). Although it stems from other assumptions than the 'human life value', our paper considers a similar dependence, confirmed by the American historical experience.

2. The U.S. Census Bureau 2021 published data concerning the average income (expressed in 2020 dollars) for the following seven age-groups: 15-24 years (noted AG1), 25-34 years (AG2), 35-44 years (AG3), 45-54 years (AG4), 55-64 years (AG5), 65-74 years (AG6), 75 years and over (AG7). The available series cover the years 1974 to 2020 for the first five groups, 1985 to 2020 for the sixth group, and 1987 to 2020 for the seventh one. In the case of the last two groups, the missing data were submitted by econometric estimations using the leads, as shown in Appendix AP4. Consequently, the symbols of the corresponding variables were completed with symbol _r. The series of the average income thus formed are organized in Appendix Ap5.

Figure 4a presents these data, for each year, as a dependence of the income level on the age-group.

Figure 4a. Dependence of the income-age ratings (IAR) on the age-groups, for the entire estimated interval



All the graphs, therefore, describe the income in correlation with the age-group as inverted U curves. The referred sample is sufficiently large (47 years) to admit such a dependence as a general characteristic of the income-age relationship. Hence it would be safe to admit the existence - for a certain historical period - of a stable enough income-age scale, based on which the macroeconomic relevance of the coexistent generations could be quantified.

3. We are aiming to shape such a scale by: i) involving annual-age groups of population, in order to obtain more precise estimations; ii) including in our analysis all the individuals aged from 16 to a century and over; iii) expressing the inter-groups income differences by using a common referential, that is in normalized values. The statistical configuration of such a scale required merging several informational sources, as well as adopting some simplifying computational conventions. DQYDJ. (2022) has published the average income per person (AVIN) for a sufficiently long list of age-groups – from 16 to 75 years (as in Table 3a).

Table 3a. Average income per person, 16-75 age-groups (AVIN1), US dollars, primary data

Age-group	AVIN1	Age-group	AVIN1	Age-group	AVIN1	Age-group	AVIN1
16	5821.3	31	59068.01	46	75233.96	61	77592.46
17	6760.37	32	58708.88	47	78354.08	62	77624.55
18	9725.23	33	59082	48	68728.45	63	77189.64
19	15062.78	34	60506.92	49	75458.16	64	73604.15
20	18513.14	35	66320.38	50	81711.22	65	74420.36
21	20712.18	36	68082.22	51	75777.31	66	79289.75
22	24447.43	37	69128.48	52	80279.55	67	93445.14
23	29814.28	38	66746.23	53	80802.58	68	84150.09
24	33164.56	39	70235.8	54	77406.45	69	82464.49
25	41461.27	40	72731.18	55	77308.78	70	76164.6
26	43945.65	41	77143.3	56	76857.49	71	76744.71
27	48376.91	42	71286.43	57	78139.14	72	98444.27
28	47399.65	43	83279.5	58	73165.04	73	92254.1
29	51638.49	44	74478.19	59	78624.85	74	70337.44
30	52706.53	45	79101.1	60	73392.66	75	70820.15

In the absence of similar statistics regarding other age-groups, for the 76 – 100 age span we used the regression $AVIN1 = f(AVIN1(-1), age, age\^{}2)$; the first term of this relationship ensures the connection of outcomes with available data, while the following induce the previously discussed inverted-U shape. The resulted estimations are displayed in Table 3b.

Table 3b Average income per person, 76-100 age-groups (AVIN2), US dollars, primary data

AGE	AVIN2	AGE	AVIN2	AGE	AVIN2	AGE	AVIN2	AGE	AVIN2
76	71900.31	81	72534.14	86	69312	91	64297.78	96	58020.9
77	72563.11	82	72091.45	87	68425.15	92	63136.4	97	56628.5
78	72897.7	83	71532.45	88	67476.33	93	61927	98	55191.66
79	72971.97	84	70874.56	89	66470.04	94	60670.74	99	53710.69
80	72837.65	85	70131.04	90	65409.66	95	59368.48	100	52185.79

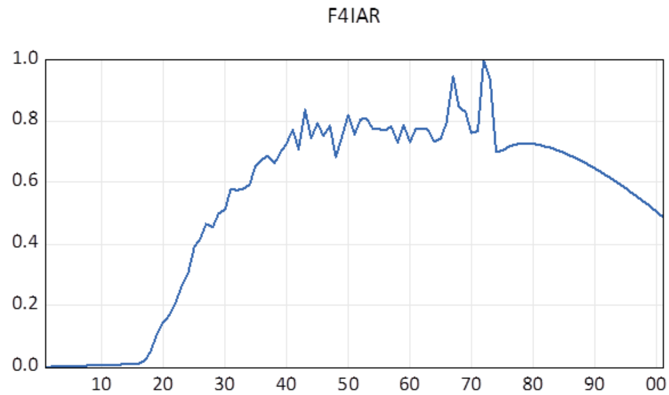
For the age-groups 1 - 15, a regression using leads was involved: AVIN1=f(AVIN1(1), AVIN1(2), the results thus obtained being described in Table 3c

Table 3c Average income per person, 1-15 age-groups (AVIN3), US dollars, primary data

AGE	AVIN3	AGE	AVIN3	AGE	AVIN3	AGE	AVIN3	AGE	AVIN3
1	4928.47	4	5114.76	7	5308.091	10	5508.729	13	5717.317
2	4989.8	5	5178.408	8	5374.145	11	5577.289	14	5785.637
3	5051.894	6	5242.849	9	5441.022	12	5646.631	15	5876.695

4. Cumulated, Tables 3a, 3b, and 3c provide a relevant statistical sample (AVIN) of the typical income-age correlation in the United States during the post Second World War epoch. In order to acquire better-structured data, this series was submitted to a normalizing operation, on which purpose we used the min-max procedure (technical details can be found, for instance, in Han *et al.* 2012 - chapter 3, Jain and Bhandare 2013, Loukas 2020, Sinsomboonthong 2022). The min-max method has the advantage of ranging terms within 0, 1 scale; the resulted coefficients are called ‘income-age ratings’ (IAR). The following figure displays the calculated income-age ratings for 81 - 100 age-groups.

Figure 4b. Dependence of the income-age ratings (*IAR*) on the age-groups, for the entire estimated interval



The U-inverted shape of these ratings is revealed clearly enough.

4. Illustrative scenario and discussion

1. The dynamic coexistence of the generations is to be simulated by an explorative model gravitating around the relationships (1) and (12), respectively:

$$POPt=UYCt\text{-}100*BSR101+UYC\,t\text{-}99*BSR100+UYC\,t\text{-}98*BSR99+\ldots$$
$$+UYC\,t\text{-}1*BSR2+UYC\,t*BSR1 \qquad (1),$$

and

$$IGRj = \Sigma icohij*IARj \qquad (12)$$

These equations are solved for the previously discussed series BSR, UCY, and IAR.

i) Data on BSR are presented in Table 4 (in online Appendix[2]).

ii) Regarding the 'under one-year children', we adopted the estimations VAR1a2b with the corrective coefficient ω=1.09, as in Table 5 in Appendix.

Table 6. Income-age rating (IAR)

Age-group	IAR	Age-group	IAR	Age-group	IAR	Age-group	IAR	Age-group	IAR
1	0	21	0.16878121	41	0.77222063	61	0.77702367	81	0.7229331
2	0.00065583	22	0.20872366	42	0.70959089	62	0.77736682	82	0.71819928
3	0.00131982	23	0.26611343	43	0.83783735	63	0.77271616	83	0.71222169
4	0.00199207	24	0.30193925	44	0.7437216	64	0.73437515	84	0.70518659
5	0.00267268	25	0.39065912	45	0.79315613	65	0.7431032	85	0.69723587
6	0.00336177	26	0.41722554	46	0.75180333	66	0.79517344	86	0.68847759
7	0.00405943	27	0.46461069	47	0.78516796	67	0.9465424	87	0.67899409
8	0.00476578	28	0.45416047	48	0.68223744	68	0.8471469	88	0.66884809
9	0.00548091	29	0.499488	49	0.75420079	69	0.82912214	89	0.65808737
10	0.00620493	30	0.51090896	50	0.82106714	70	0.76175502	90	0.64674831
11	0.00693807	31	0.57893468	51	0.75761358	71	0.76795836	91	0.63485865
12	0.00767957	32	0.57509437	52	0.80575774	72	1	92	0.6224395
13	0.00843545	33	0.57908428	53	0.8113507	73	0.93380616	93	0.60950695
14	0.00916602	34	0.59432149	54	0.77503459	74	0.69944298	94	0.59607325
15	0.01013973	35	0.65648703	55	0.77399017	75	0.70460478	95	0.58214775
16	0.00954737	36	0.67532706	56	0.76916436	76	0.71615531	96	0.56773754
17	0.0195892	37	0.68651511	57	0.78286953	77	0.72324293	97	0.55284806
18	0.05129358	38	0.66104081	58	0.72967958	78	0.72682081	98	0.53748342
19	0.10837003	39	0.69835611	59	0.78806341	79	0.72761502	99	0.52164677
20	0.14526604	40	0.72504015	60	0.73211361	80	0.72617867	100	0.50534051
								101	0.48856646

The simulations are centered on three areas: the age-structure of the population, the generations coexistence, and the income generational relevance.

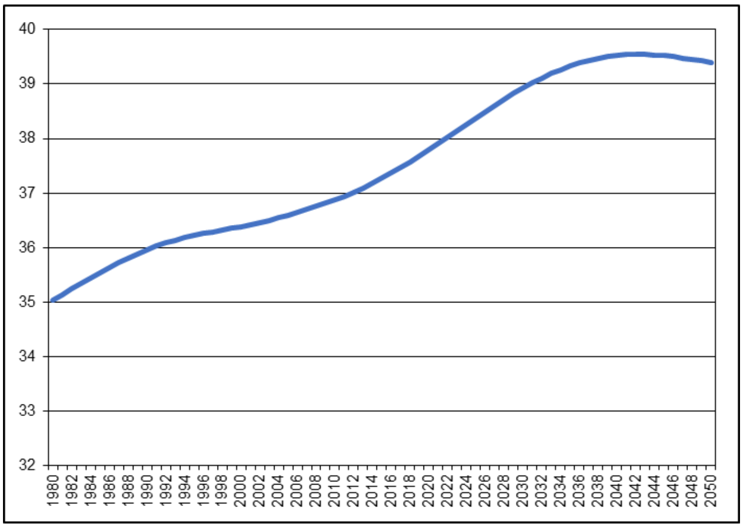
2. The dynamics of the age-structure is characterized in Table 7 (in Appendix).

The weight of the young segment of population (between 1-25 years) registers a descending trend, compensated by the aging segments.

Globally, there is observed a clear ascending trend of the average age (weighted) of population (Figure 5).

2 *The Appendix is available online as Supplemental material.*

Figure 5. Average age (weighted) of the total population



Both the demographic age-groups and the average age undergo a certain wave-like evolution.

3. The dynamics of the generational structure is presented in Appendix Ap6, which elaborates on the shares of the coexistent generations in total population (identified by *sh_j_POP*, where *j* is the symbol of the generation) resulted from the model simulations for the time span 1980 - 2050. Three sub-periods of this interval stand out:

i) The final years of the twentieth century are characterized by the exit from the historical scene of the Pre-lost and Lost generations; Greatest, Silent, Baby, and X generations are dominant, however under an overall descending trend.

ii) The first quarter of the twenty-first century is marked by the exit of the Greatest generation and the rapidly diminishing role of the Silent one; the X generation is prioritized; despite remaining significant, the weight of the Y generation stabilizes and begins to decrease.

iii) The prospect for 2021 - 2050 emphasizes:

▪ the contraction to disappearance of the Greatest and Silent generations;

▪ a moderate decline of Baby boomers, generation X, and Millennials;

▪ the appearance and expansion, followed by a quasi-stabilization, of the Alpha generation;

▪ the emergence and vigorous affirmation of the Beta generation.

4. These features of the generational structure dynamics are valid for the population as such. The same approach reveals a somehow different picture in the case of the income generational relevance (IGR_j), which takes into account not only the population size, but also its income-age distribution. It summarizes the income-age ratings of all the inhabitants belonging to the respective generation (relationship 12). The shares of the different generations in total IGR (sh_j_IGR) are estimated as follows:

$$sh\_j\_IGR = IGRj/\Sigma iIGRj \quad for\ j=pL, L, G, S, Bb, X, Y, Z, A, B \tag{13}$$

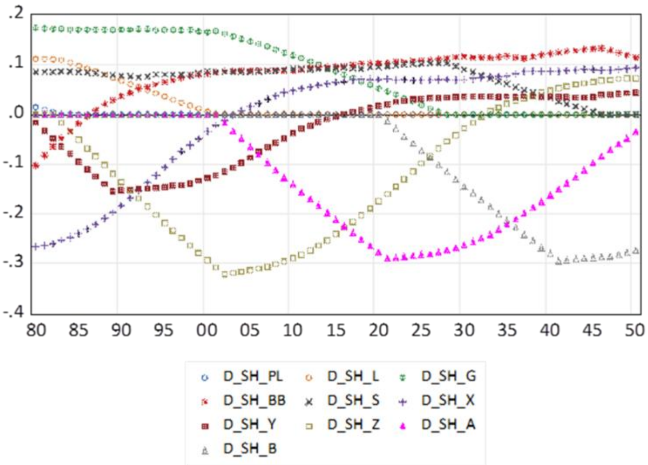
Appendix Ap7 contains the shares of the coexistent generations in the total income generational relevance (noted sh_j_IGR, where j is the symbol of generation), resulted from the model simulations for the time span 1980 - 2050.

5. In order to compare Appendices 6 and 7, we calculated the differences between two of the above presented distributions (depending on IGR and on POP):

$$d\_sh\_j = sh\_j\_igr\text{-}sh\_j\_pop \quad (14)$$

where *j* is the symbol of the generation. Figure 6 displays the dynamics of these differences during the entire simulated interval.

Figure 6. Dynamics of the differences *d_sh_j*



In the case of generations pL, L, G, and S these differences are positive, whereas the last two (A and B) are negative. The remaining generations (Bb, X, Y, and Z) are characterized by differences shifting from negative to positive. A possible integration of the results discussed in our paper into the Generation power index (Moss 2017, Desjardins 2021, Najib 2021) should require further statistical and socio-economic research.

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