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Cross-Country Inequality: A Markov Chain Approach

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About the topic

- This paper was started before pandemic … to investigate specific aspects of inequality transition processes in the past decades …
- Covid-19 shock is determining significant effects on inequality (e.g., Ghosh, 2020) … not considered – at moment - in this preliminary paper …
- The importance of investigating inequality is reinforced by pandemic shock

Aim of the Paper

- The aim of the paper is to study the **dynamics of inequality in a large set of countries in the past two decades** (and to make a forecast for the next two decades).
- As measures of inequality we considered the **gross national income per capita** (GNI) in PPP and the **human development index** (HDI).

Approach

- In both cases, we divided the countries into **5 classes** and used the Markov chain approach with the **estimation of the transition matrix** to describe the processes that take place, and create a forecast.

Data

- A for **GNI**, we considered **189 countries for the period 1995-2018**. To separate countries into classes, we used the approach from seminal paper of Quah (1993) and split all countries into 5 classes.
- As for **HDI**, due to data availability, we considered **179 countries for the period 2000-2018**. HDI indicators were normalized (0-1) and all countries were divided into 5 classes.

Key Results (1)

- In both cases, the processes turned out to be Markov first-order.
- However, as for GNI the transition probability matrix was statistically different for the periods 1995-2006 and 2006-2018, so we calculated the marginal distribution and made a forecast based on the second matrix.
- As for HDI the transition probability matrix was homogeneous for the entire time period.

Key Results (2)

- Considering the Shorrock's Index, detecting the degree of mobility of countries between classes, we found that countries are less mobile considering HDI with respect to per-capita GNI.

Empirical results (1)

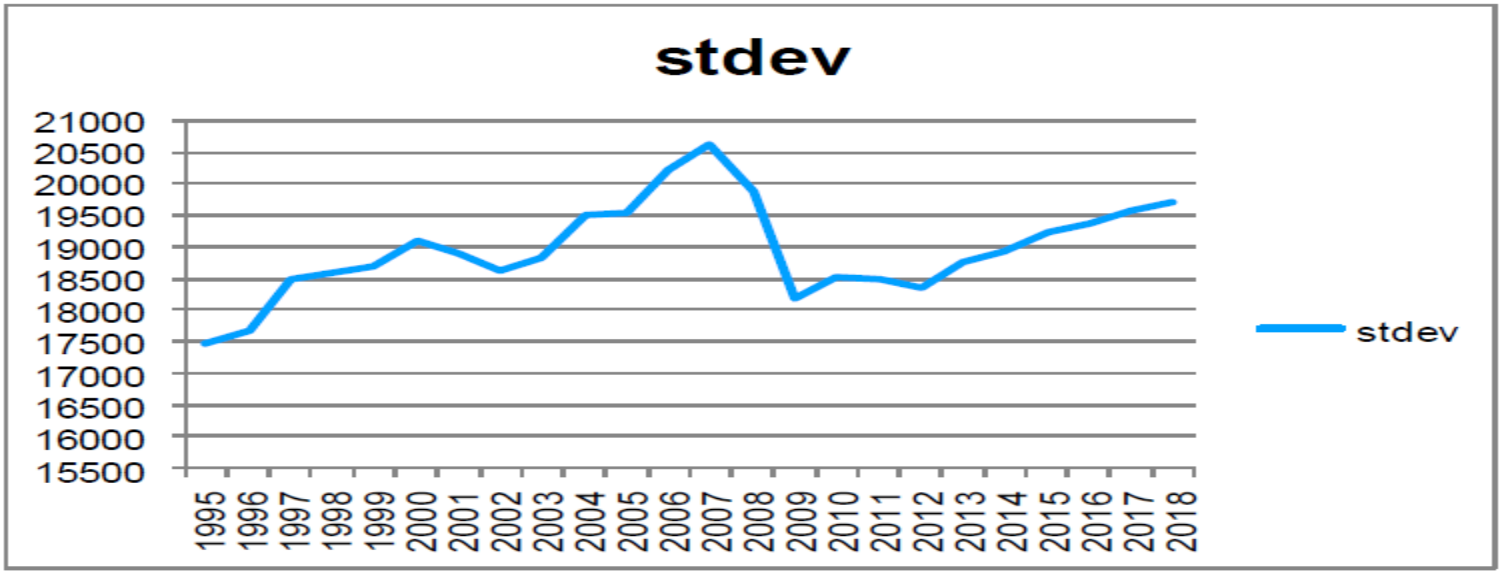
- GNI – **gross national income per capita** at purchasing power parity (at base prices of 2011), period: 1995 – 2018.
- First result: sigma and beta convergence/divergence.
- **per-capita GNI in the selected 189 countries and period 1995-2018 determined a i) absolute beta-convergence and a ii) prevailing sigma divergence (standard deviations)**

Empirical results (2)

Estimating regression $\frac{1}{23}\ln\frac{GNI2018}{GNI1995} = \beta_0 + \beta_1 GNI1995 + \varepsilon$

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.068796996	0.00940168	7.31752219	7.23E-12	0.05025	0.087344
lnGNI1995	-0.005324216	0.00106664	-4.99159456	1.37E-06	-0.00743	-0.00322

Appendix 3. The results of standard deviation estimation



Details on the 5 classes

- For a more detailed study of the processes of changing per capita incomes of residents of different countries, we divided all countries into 5 classes according their GNI in 1995. We used the similar boundaries to Quah (1993) who splitted all countries into 5 classes: the first (the poorest) class, countries with GNI values of no more than 20% of the average for all countries were included, in the second - from 20% to 50% of the average for all countries, in the third - from 50% to 100% from the average for all countries, in the fourth - from 100% to 200% of the average for all countries and in the fifth class - more than 200% of the average for all countries.

Empirical results (3)

- We calculated transition probability matrix. In order to be able to study the long-term trends in the dynamics of countries using this matrix, **it is necessary to verify that this transition matrix is Markov first-order (depended only on the situation at the previous year, but not earlier) and homogeneous (not statistically changing over time)**. To test these properties, the tests from the article (Bickenbach F., Bode, 2003) were used. **The Markov property of the transition matrix was confirmed, but the homogeneity (equality in time periods 1995-2005 and 2006-2018) was not confirmed**. Possibly, this was due to the fact that dynamics of economy has changed after the economic crisis in 2007-2008. Therefore, we decided to use the transition matrix for 2006-2018.

Empirical results (4)

Table 1. Transition probability matrix (GNI)

Group in t-1 period	Group in t period				
	1	2	3	4	5
1	0,97058824	0,02941176	0	0	0
2	0,0212766	0,95390071	0,0248227	0	0
3	0	0,0102459	0,95696721	0,03278689	0
4	0	0	0,02258065	0,96129032	0,01612903
5	0	0	0	0,0097561	0,9902439

- This matrix has large diagonal elements, i.e. the probability of moving to another class is small.
- Shorrock's Index, characterizing the degree of mobility of countries between classes, is equal to 0.0418, showing a quite low mobility of countries.

Empirical results (5)

- **Nevertheless, changes, although slowly, are taking place.** Table 2 shows the share of countries in each of the 5 classes over several years. **If in 2006 the share of countries in the first and second classes (the poorest) was almost 50%, then in 2018 it was already 43%. We calculated forecasts for 10 and 20 years and we see that the forecasted share of countries included in 1 and 2 classes should be reduced to 39.8% in 2030 and 37.4% in 2040.** At the same time share of countries in 4 and 5 classes was 30.2% in 2006 and according our forecast increase till 37.1% in 2030 and 39.9% in 2040.

Empirical results (6)

Table 2. Distribution of countries between five classes (GNI)

Class	% of mean income	Shares 2006	Shares 2018	Predicted Shares 2020	Predicted Shares 2030	Predicted Shares 2040	Limiting distribution
1	< 0.2	0.270	0.228	0.223	0.202	0.186	0.054
2	0.2-0.5	0.217	0.201	0.201	0.196	0.188	0.074
3	0.5 - 1	0.212	0.243	0.24	0.231	0.227	0.180
4	1 - 2	0.138	0.175	0.18	0.200	0.212	0.261
5	>2	0.164	0.153	0.156	0.171	0.187	0.431

Empirical results (8)

- However, in addition to income, the well-being of residents of different countries is also measured using other indicators that take into account life expectancy at birth, educational level, etc. One of the most popular indicators is the **Human Development Index**, which we used to test the robustness of the results.

Empirical results (9)

- For HDI data was available only since 2000 and we used data for 179 countries.

To compare the HDI dynamics for different years, we converted its values as follows:

$$HDI^{*}_{it} = \frac{HDI_{it} - \min\limits_{j} HDI_{jt}}{\max\limits_{j} HDI_{jt} - \min\limits_{j} HDI_{jt}} \text{ for each country } i = 1,\text{K},179 \text{ and each year } t = 2000,\text{K},2018.$$

- Modified variables take values in the interval [0, 1] for each year. After that, we set the boundaries of this indicator for 5 classes so that in 2000 the number of countries in each class was approximately the same.
- The first class includes countries with calculated values from 0 to 0.3. The second class consists of countries with values from 0.3 to 0.5, the third class with values from 0.5 to 0.65. The fourth class includes countries with a value of the indicator from 0.65 to 0.8. All countries with greater values of HDI* belong to the fifth group.

Empirical results (10)

- We also calculated transition probability matrix and tested that this matrix is Markov first-order and homogeneous.

Table 3. Transition probability matrix (HDI)

Group in t-1 period	Group in t period				
	1	2	3	4	5
1	0,97916667	0,02083333	0	0	0
2	0,01195219	0,98207171	0,0059761	0	0
3	0	0,00153846	0,96461538	0,03384615	0
4	0	0	0,01445087	0,96242775	0,02312139
5	0	0	0	0,0132626	0,9867374

Empirical results (11)

- **Shorrock's Index**, which characterizes the degree of mobility of countries between classes, is equal to 0.0312, **smaller than in previous case**. **This tells us that countries are less mobile if we use HDI.**

Empirical results (12)

- Table 4 shows **shares of countries in each of the 5 classes over several years. If in 2000 the share of countries in the first (less developed) class was 22%, then in 2018 it was already 18%.**
- **We calculated forecasts for 10 and 20 years** and we see that **the forecasted share of countries included in 1 class should be reduced to 16.2% in 2030 and 15.1% in 2040** (in 2000 it was 22.3%). In the long term the share of the most developed countries (4 and 5 class) will be more than 50% in the 2030 and 2040 (in 2000 it was 39.6%).

Empirical results (13)

Table 4. Distribution of countries between five classes (HDI)

Class	HDI*	Shares 2000	Shares 2018	Predicted Shares 2020	Predicted Shares 2030	Predicted Shares 2040	Limiting distribution
1	< 0.3	0.223	0.184	0.177	0.162	0.151	0.019
2	0.3-0.5	0.134	0.162	0.169	0.176	0.179	0.033
3	0.5 – 0.65	0.246	0.190	0.178	0.161	0.150	0.128
4	0.65 – 0.8	0.184	0.218	0.228	0.233	0.234	0.299
5	0.8 – 1	0.212	0.246	0.249	0.268	0.285	0.521

Key Conclusion

- **The generally positive dynamics also include some inertia – especially for HDI - and this result strongly suggest the adoption of appropriate policies to favor upward beta convergence on per capita GNI and, especially, on HDI.**

Further research developments

- **When data for 2019 and 2020 becomes available, it will be interesting to compare:**
- **1) how COVID affected distribution of countries by 5 classes, how much will this distribution differ from predicted shares 2020 (for GNI and HDI)**
- **2) how much the transition probability matrix will change (for GNI and HDI)**
- **3) how much the limiting distribution for new transition probability matrix will change (for GNI and HDI).**

THANKS!

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Appendix 1. List of countries

Number	Country	Number	Country	Number	Country
1	Afghanistan	64	Georgia	127	Norway
2	Albania	65	Germany	128	Oman
3	Algeria	66	Ghana	129	Pakistan
4	Andorra	67	Greece	130	Palau
5	Angola	68	Grenada	131	Palestine
6	Antigua and Barbuda	69	Guatemala	132	Panama
7	Argentina	70	Guinea	133	Papua New Guinea
8	Armenia	71	Guinea-Bissau	134	Paraguay
9	Australia	72	Guyana	135	Peru
10	Austria	73	Haiti	136	Philippines
11	Azerbaijan	74	Honduras	137	Poland
12	Bahamas	75	Hong Kong, China (SAR)	138	Portugal
13	Bahrain	76	Hungary	139	Qatar
14	Bangladesh	77	Iceland	140	Romania
15	Barbados	78	India	141	Russian Federation
16	Belarus	79	Indonesia	142	Rwanda
17	Belgium	80	Iran (Islamic Republic of)	143	Saint Kitts and Nevis
18	Belize	81	Iraq	144	Saint Lucia
19	Benin	82	Ireland	145	Saint Vincent and the Grenadines
20	Bhutan	83	Israel	146	Samoa
21	Bolivia (Plurinational State of)	84	Italy	147	Sao Tome and Principe
22	Bosnia and Herzegovina	85	Jamaica	148	Saudi Arabia
23	Botswana	86	Japan	149	Senegal
24	Brazil	87	Jordan	150	Serbia
25	Brunei Darussalam	88	Kazakhstan	151	Seychelles
26	Bulgaria	89	Kenya	152	Sierra Leone
27	Burkina Faso	90	Kiribati	153	Singapore
28	Burundi	91	Korea (Republic of)	154	Slovakia
29	Cabo Verde	92	Kuwait	155	Slovenia
30	Cambodia	93	Kyrgyzstan	156	Solomon Islands
31	Cameroon	94	Lao People's Democratic Republic	157	South Africa
32	Canada	95	Latvia	158	Spain
33	Central African Republic	96	Lebanon	159	Sri Lanka
34	Chad	97	Lesotho	160	Sudan
35	Chile	98	Liberia	161	Suriname
36	China	99	Libya	162	Sweden
37	Colombia	100	Liechtenstein	163	Switzerland
38	Comoros	101	Lithuania	164	Syrian Arab Republic
39	Congo	102	Luxembourg	165	Tajikistan
40	Congo (Democratic	103	Madagascar	166	Tanzania (United

	Republic of the)				Republic of)
41	Costa Rica	104	Malawi	167	Thailand
42	Croatia	105	Malaysia	168	The former Yugoslav Republic of Macedonia
43	Cuba	106	Maldives	169	Timor-Leste
44	Cyprus	107	Mali	170	Togo
45	Czechia	108	Malta	171	Tonga
46	Cфte d'Ivoire	109	Marshall Islands	172	Trinidad and Tobago
47	Denmark	110	Mauritania	173	Tunisia
48	Djibouti	111	Mauritius	174	Turkey
49	Dominica	112	Mexico	175	Turkmenistan
50	Dominican Republic	113	Micronesia (Federated States of)	176	Tuvalu
51	Ecuador	114	Moldova (Republic of)	177	Uganda
52	Egypt	115	Mongolia	178	Ukraine
53	El Salvador	116	Montenegro	179	United Arab Emirates
54	Equatorial Guinea	117	Morocco	180	United Kingdom
55	Eritrea	118	Mozambique	181	United States
56	Estonia	119	Myanmar	182	Uruguay
57	Eswatini (Kingdom of)	120	Namibia	183	Uzbekistan
58	Ethiopia	121	Nepal	184	Vanuatu
59	Fiji	122	Netherlands	185	Venezuela (Bolivarian Republic of)
60	Finland	123	New Zealand	186	Viet Nam
61	France	124	Nicaragua	187	Yemen
62	Gabon	125	Niger	188	Zambia
63	Gambia	126	Nigeria	189	Zimbabwe