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RESEARCH

Global (Dis)Similarity between Human Development and Demographic Reproduction and its Spatial Entropy from 1970 to 2020

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Abstract

This study proves new manifestations of (dis)similarity between the levels of human development and demographic behavior. The primary research question is whether the set of populations of the world's countries behaves demographically "in accordance" with the level of their human development. This seems like a trivial demographic question that has been addressed by a lot of demographers in the last decades. However, we think that a new perspective can still be brought to the topic. It turns out that the investigated relationship is not as crystal clear as it might seem. We have developed an original index of human development. Moreover, we dealt with a set of 195 countries as well as quite a long period−from 1970 to 2020. The first key finding is that human development and demographic behavior have become increasingly similar – more than expected; roughly twice as much in 2020 as in 1970. We also investigated whether people's affiliation with respective world region has a changing contribution to the global variety of relationship between human development and demographic behavior. The main finding is that the contributions of spatial dimensions (continents, macro-regions, countries) to mutual dissimilarity between human and demographic developments change over time.

Keywords Demographic reproduction · Human development · Global dissimilarity · Spatial inequalities · Spatial entropy

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Introduction

"In poor countries, more children are born, more children die, and people live shorter lives". Graphs illustrating the statistical dependance between the GDP (HDI) and the number of children born to one woman, or analogous graphs, may be found throughout demography textbooks and on the internet. Indeed, the causal link between the level of socio-economic (human) development and that of demographic reproduction[1] does not −at first sight−arouse stronger controversy in the scientific debate. Since the time of thought makers of the demographic revolution – transition (Thompson, 1929; Landry, 1934; Davis, 1945), there has been consensus that changes in demographic behavior are a direct consequence of social progress, particularly after the onset of the industrial revolution. While the demographic transition took a very long time in the first emerging industrial powers, it occurred very quickly in the developing world. Here, the demographic "scissors" between the birth rate and the death rate opened extremely wide. One of the consequences is the following population explosion and forecasts by the Club of Rome (Meadows et al., 1972) or Ehrlich (1968). The ideas of neo-Malthusians persist to this day, but – of course – they are also subjected to sharp, often justified, criticism (Eberstadt, 2014).

Simply put, the more advanced a country is in social/socio-economic development and the higher its level of human development, the longer its inhabitants live, and the fewer children have. In other words, the country's demographic behavior and reproduction patterns differ. But is this relation really that clear? The text above might seem trivial from the point of view of demography. Nevertheless, we tried to "brush off" these ideas and bring a new quantification of the relationship. As we show, not all is crystal clear in these relations. For example, the relation between the GDP or HDI and the total fertility rate is well-known. However, there are also studies (e.g. Myrskylä et al., 2009; Luci-Greulich & Thévenon, 2014) pointing out that, beyond a certain level of development, this relation is not so unequivocal, even at the subnational level (Fox et al., 2019). The so-called second demographic transition (Lesthage & Van De Kaa, 1986) also plays a role; it has had the greatest impact on the group of the most developed countries in the world. At the same time, the weak correlation between a country's level of development and its total fertility rate within the OECD countries is influenced by the population and family policies as well as the possibilities for harmonizing family and work life (McDonald, 2006; Gauthier, 2007; Thévenon 2011).

To make it even more complicated, besides intensity – quantum, tempo – the timing of processes also changes, for example: the mean age at marriage, the mean age at first birth, or the inter-birth intervals. That is also why, over the last three decades, methods have been developed to account for changes in timing when calculating intensity (Bongaarts & Feeney, 1998), including the incorporation of parity (Kohler

[1] Throughout the study, we use "human development" or "index of human development" in its unabridged form to distinguish it from the "official" UN Human Development Index (HDI). We alternatively use the terms demographic reproduction/behavior in case of demographic development. Thus, the demographic development is expressed by basic indicators of demographic reproduction. The terms behavior and reproduction are used alternatively like synonyms although there can be different understanding of them in demographic studies.

& Ortega, 2002; Zeman et al., 2018). Life expectancy – as a synthetic and undoubtedly the best indicator of mortality – may also fail to capture specific characteristics, such as the difference in life expectancy between men and women, the contribution of the children component to overall mortality, and others.

We point out that our interest is not to uncover patterns of divergence or convergence in global demographic development as such, which is one direction in demo-geographic research using several types of convergence models or convergence "clubs". In this concern, some of the very comprehensive studies represent those from Moser et al., 2005; Dorius, 2008; Wilson, 2011 and several others.

Discussions can also be conducted about the bidirectionality of the relation. In statistical terms, is the level of human development predominantly an independent variable, or on the contrary, does demographic development affect social one? For instance, Adam Smith already argued that demographic reproduction is subordinate to economic reproduction (Otesson 2002). In forecasting studies, this relation is much debated, notably in the direction that social patterns and human development influence demographic development (Lutz et al. 2017; Gailey & Lutz, 2019). It is beyond doubt that the relation can be understood from the opposite perspective as well. Moreover, demographic reproduction can be viewed only as a subset of human development, one of its dimensions. After all, one of the dimensions of human development within the HDI is one of the fundamental demographic indicators – life expectancy. However, we strictly distinguish between the two concepts and treat them independently in this study.

Regarding human development, we (like several other authors mentioned below) consider the HDI introduced in the early 1990s to be an important basic indicator. Nevertheless, it is simply not enough to express the complex reality of the 21st century. Any defined indicator of development should be as comprehensive as possible to best capture also the quality of life, well-being and happiness. These concepts should overlap with that of human development and are also proposed in rethinking the HDI. There are also opinions that "increasing the number of HDI dimensions does not seem to be the most promising way of enhancement of the HDI" (Comim, 2016).

Quite predictably, since the introduction of the essentially simple HDI more than 30 years ago, alternative views of what the indicator could look like have emerged. An augmented HDI has been presented, in which healthy life expectancy, quality-adjusted years of schooling, material living standards and political freedom appear at the global level (Prados de La Escosura, 2021). A Bayesian factor analysis has also been suggested, using three auxiliary variables capturing environmental health and sustainability, income inequality, and a satellite-observed night light model (Qiu et al., 2018). Some authors emphasize the importance of subjective indicators and the fact that these are still rather rejected (Nussbaum, 2000). Of the partial dimensions, unemployment is proposed (Taner et al., 2011). Attention has been paid to suggestions on how to measure inequality, for example, through the Gini coefficient (Paul, 1996; Hicks, 1997). Regardless of the search for the "right" partial indicators, data inaccuracies remain a major challenge for the HDI (Castles, 1998). Structural changes in the goalpost values and unexplained trade-offs in the HDI indices are also a problem (Ghislandi et al., 2019).

In this study, we propose our own indicators to evaluate human development. Since we aimed to cover the longest possible period for all countries of the world, any sophisticated idea of measuring human development collides with the harsh reality of available data. Nonetheless, we present a relatively wide range of dimensions and partial variables, which are partly based on studies published previously. As our objective is to correctly measure the relation between human and demographic developments, we consider a 50-year period to be the minimum time span. During it, even demographic transformational changes can fully manifest themselves, revealing the evolution of relations between human and demographic developments, as well as their similarities or dissimilarities. As already mentioned, we are aware of several issues with the HDI. Thus, we wished to find a reasonable compromise between measurability and comprehensiveness, which is also discussed in the criticism of the HDI (Sagar et al. 1998; Wolf et al. 2011).

As in the evaluating and measuring of human development, there is no clear definition or a precise set of indicators to reflect the level of demographic reproduction. There exist narrower and broader definitions of demographic (population) reproduction and reproductive behavior. For the purposes of this study, we prefer a narrow understanding that employs indicators of (demographic) fertility and mortality as the two fundamental processes driving generational change. Family behavior, represented mainly by marriage and divorce, is also a valuable characteristic, however, any effort to include them again runs into the reality of demographic data available. Their measurement in the 1970 s in the developing world is almost impossible not only due to the absence of relevant data. A special problem is whether to include migration. Its nature is more complex (Hochshild & Mollenkopf 2018). We had the longest time thinking about migration. In the end, we did not include it in the primary model for two reasons. The main one was the assumed inaccuracy of the migration balance in the case of many developed countries, not to mention the fact that mirror statistics also in the case of European countries speak of undocumented migration.

The primary research question is whether the set of populations of the world's countries behaves demographically "in accordance" with the level of their human development. That implies we correlate human and demographic developments. We understand them autonomously, though their partial overlap is evident. Is their interrelation closer now than it was, or contrariwise, are they more similar in 2020 than 50 years ago? Global values are always the sum of individual country values. But what is the contribution of the countries to those global values that measure the relation between human and demographic developments? Therefore, we also measure local contributions to global values. It is important to mention that after World War II, geopolitical, socio-economic milestones on the one hand, and demographic milestones on the other hand, overlapped (or, conversely, followed each other) over time. For example, the Oil crisis in 1970 s affected migration. But it was also induced by geopolitical changes and wars after 1989. Unlike the oil crisis, the events after 1990 also dramatically affected fertility. At the same time, however, migration entered a complex phase, where it is influenced by a full range of factors unlike the earlier period, primarily with strengthening globalization. We mention this to get closer to the perspective of different manageability of demographic and overall human developments. Demographic development is to some extent managed, especially in terms of mortality, but also through family policies and fertility. Of course, migration is also managed through migration and asylum policies. Nevertheless, the process is autonomous. People are moving despite restrictions, smugglers have been active for decades, every geopolitical turbulence triggers a larger or smaller migration wave. Fertility is declining despite the efforts of central governments. On the other hand, social and economic (human) development, the well-being of populations are ore can certainly be more influenced by paternalistic interventions, at least in view of developmentalism theory (Bresser-Pereira & Oreiro, 2024). This is also a key point of view when examining the mutual relationship of the two dimensions. One more and the other less influenced, one would expect their convergence to be negligible or slow. Despite the critique (e.g., that it is too simplifying) some revival of such thoughts came after the last economic recession 2007–2009. But "developmental thinking" occurred though less often, in demography as well. Thornton and Philipov (2007) elaborated on this idea using the example of post-communist countries. They point out the importance of developmental models in guiding change in the region, suggesting that developmental idealism influenced family and demographic changes following the political transformations. As these countries moved economically towards the "Western" model, they gradually began to resemble it demographically. The question is whether this Western model represents a kind of terminal stage towards which all countries of the world, semi-periphery countries and eventually peripheral countries in the context of globalization, are converging and will converge with certain variations.

The second question is whether there exist certain similarities or attributes within continents and macro-regions that distinguish them from each other. To figure out this, we use the concept of spatial entropy with the Theil index. Thus, we can reveal patterns of changes in the contributions of intercontinental and intra-regional differences to total inequality. Simply said, we ask whether there are more differentials between the macro-regions, subregions, or countries. Theoretical background here lies in the theory of stages. Despite a few shortcomings, the stage theory stands for an ideal theoretical basis for us due to its simplicity and other possibilities for its development. Hampl (1994) divides the phases according to the significant changes in economic sectors into static (pre-industrial period alternative), dynamic (industrial) period and organic (post-industrial) period phases. What is important from our point of view is the fact that the later the phase, the higher the degree of hierarchization and hierarchical organization. The components of the total inequality can thus help to at least partially uncover patterns of hierarchization in the development of the socio-economic and demographic systems.

When speaking about spatial inequalities and their components and spatial entropy in general, we should start with small overview. The term "inequality" has a long history and is used in various contexts, from mathematics to social and economic theory. Its use in mathematics dates to ancient times. Specifically, the Greek mathematician Euclid (4th century BC) in his work "Elements" (*Elementa* in Latin) presents several statements about geometric inequalities (Smorynski, 2008). In the socio-economic context, the term "inequality" began to occur more often during the Enlightenment. Prominent economists, such as John Maynard Keynes and Thomas Piketty, also dedicated themselves to documenting inequalities (Ekelund & Hébert, 2013). Sociologists provided a broader belief of the concept. For example, Max Weber and Pierre Bourdieu studied different approaches to education, health care, rights and opportunities (Stolley, 2005). The concept of inequality is also key in geography, which focuses precisely on the mapping of spatial inequalities, sometimes referred to as disparities or differentiations.

Methods

Selection of Indicators and their Grouping

We analyze 195 countries (those with more than 100,000 inhabitants in 1970) between the years 1970 and 2020. Both synthetic dimensions – the index of human development and the index of demographic development (Level 3) – consist of subdimensions (Level 2), in the form of semi-synthetic indicators. Each of them is made up of several partial indicators (Level 1). A summary overview is provided in Table 1.

When testing the variables (environmental index, income index, index of health and nutritional conditions, inequality index, educational index, index of spatial interaction) that explain the variability of human development, we used multiple regression. More about mathematical notation and evaluation methods for regression analysis can be found in Field (2018). It was precisely the linear regression method that helped us identify those components of the level of human development, which could be behind the existing spatial disparities in the components of demographic reproduction.

For each year separately (1970, 1980, 1990, 2000, 2010), three variants of regression models were constructed: for the fertility index, the mortality index, and the index of demographic development, respectively. Thus, in a total of 18 models, we assessed the significance level (Sig.<0.05) of the individual indices as well as their collinearities through the so-called VIF factor. Based on these criteria, in the calculation of the final index of human development, we included only the income index, index of health and nutritional conditions, inequality index, and educational index, but not the index of spatial interaction and environmental index. The index of spatial interaction showed a weak significance level in most models, while the environmental index was too closely related to the income index. Considering their availability, the indicators from Level 1 were designed for all countries and the entire period (Appendix 2).

Input Indicators and the Method of Standardization

The initial step in data processing involved standardizing the real values of the analyzed indicators to the values ranging from 0 to 1. The standardization method was inspired by procedures used for the calculation of the Human Development Index (United Nations Procurement Division, 2022). The minimum and maximum values

Table 1 Indicators of human development and demographic development at various levels

Level and name of indicator			Calculation			
Level 3 = total index **	Level 2 = sub-dimension index **	Level 1 = index for indicator	Function		Indicator value for:	
			Logarithmic	Inverse	Min. (index = 0)	Max. (index = 1)
Index of human development Index of human development	Environmental index Not included in the calculation finally ***	CO_2 emissions in tons per capita[1]	YES*	YES	25	0,1
		Carbon footprint per capita[1]	YES*	YES	15	1,0
		Renewable internal freshwater resources per capita[1]	YES*		150	15 000
	Income index	Average daily income per capita[1]	YES*		2	50
		Real GDP per capita in 2011 in $[5]	YES*		100	75 000
	Index of health and nutritional conditions	Food supply in kilocalories per person[1]			1 500	2 500
		Share of one-year-olds who are vaccinated against at least one disease[1]			35	95
		Maternal mortality ratio[1]		YES	400	10
	Inequality index	Gini coefficient (index of income inequality)[1]		YES	80	20
		Gender inequality index[1]			10	90
		Civil liberties index[1]		YES	7	1
	Educational index	Expected years of schooling[2]			0	18
		Mean years of schooling[2]			0	15
	Index of spatial interaction Not included in the calculation finally ****	Percentage of population residing in urban agglomeration with over 300,000 Inhabitants[4]			5	80
		Percentage of population in urban areas[4]			10	90

Table 1 (continued)

Level and name of indicator			Calculation			
			Function		Indicator value for:	
Level 3 = total index **	Level 2 = sub-dimension index **	Level 1 = index for indicator	Logarithmic	Inverse	Min. (index = 0)	Max. (index = 1)
Index of demographic development	Fertility index	Age-specific fertility rate at 15–19[3]		YES	200	3
		Total fertility rate[3]		YES	7,6	1,5
	Mortality index	Infant mortality rate[3]		YES	115	5
		Life expectancy at birth[3]			20	85
	Migration index Not included in the calculation finally	Crude net migration rate[3]			−10	5
		Crude net migration rate (previous 10 years)[3]			−10	5

* Large differences between countries in these indicators. The coefficient of variation is greater than 100% for each year

** Higher levels are calculated as the geometric mean of lower levels

*** Excluded from calculations based on partial results of regression analysis between the Level 2 indicators of human development and demographic development. Regression models are presented in Appendix 2

Reason for exclusion from further analysis: the environmental index showed strong collinearity with the income index (VIF > 5). Using two similar indicators could distort the results

**** Excluded from calculations based on partial results of regression analysis between the Level 2 indicators of human development and demographic development. Regression models are presented in Appendix 2

Reason for exclusion from further analysis: the index of spatial interaction was not significant in explaining the components of demographic development (in only one model was sig. <005). The effect of this indicator is weak in the models. Also, by removing this variable, we simplify the model and reduce "noise"

Sources: [1] (Gapminder, 2023)

[2] (United Nations Procurement Division, 2023)

[3] (United Nations, 2023a)

[4] (United Nations, 2023b)

[5] (Groningen Growth and Development Centre, 2023)

(goalposts) were set to transform the indicators expressed in various units into the indices between 0 and 1. These goalposts serve as the "natural zeros" and "aspirational targets", respectively, for the standardization of the component indicators. Standardization was executed using different procedures " (see Eq. 1 below), which were derived from the type of statistical distribution and the way of perceiving negative "natural zeros" and positive values "aspirational targets":

	Direct version	Inverse version	
Linear function	$I = \frac{x_i - x_{min}}{x_{max} - x_{min}}$	$I = \frac{x_{max} - x_i}{x_{max} - x_{min}}$	(1)
Logarithmic function	$I = \frac{\ln x_i - \ln x_{min}}{\ln x_{max} - \ln x_{min}}$	$I = \frac{\ln x_{max} - \ln x_i}{\ln x_{max} - \ln x_{min}}$	

I is index for indicator, x_i is value of indicator in country i, x_{min} is minimal value of indicator, x_{max} is maximum value of indicator. The use of each standardization procedure for the analyzed indicators is shown in Table 1.

The resulting indicators are two final indices (one for human development and one for demographic development), They are formed by individual sub-dimensions and consist of two or three partial indicators (see Table 2). The sub-dimensions as well as the indices are always calculated as the geometric mean of lower-level indicators. Some indicators are inherently inverted.

Calculating Global and Local Dissimilarities

We compared the final values of the index of human development and those of the index of demographic reproduction using the population weighted index of dissimilarity (IN). Its mathematical notation has the following form:

Table 2 Correlation index between the sub-indicators of human development and demographic development

Year 1970	Income index	Index of health and nutritional conditions	Inequality index	Educational index	Fertility index	Mortality index
Income index		0.70	0.58	0.79	0.63	0.77
Index of health and nutritional conditions	0.70		0.61	0.79	0.81	0.85
Inequality index	0.58	0.61		0.67	0.65	0.71
Educational index	0.79	0.79	0.67		0.75	0.84
Fertility index	0.63	0.81	0.65	0.75		0.85
Mortality index	0.77	0.85	0.71	0.84	0.85	
Year 2020						
Income index		0.80	0.65	0.89	0.82	0.84
Index of health and nutritional conditions	0.80		0.57	0.80	0.81	0.85
Inequality index	0.65	0.57		0.70	0.56	0.62
Educational index	0.89	0.80	0.70		0.81	0.84
Fertility index	0.82	0.81	0.56	0.81		0.89
Mortality index	0.84	0.85	0.62	0.84	0.89	

Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

$$IN = \sum_{i=1}^{n} LIN_i . \frac{n_i}{n} \text{where} LIN_i = \left| \frac{x_{ILR_i}}{\overline{X}_{ILR}} - \frac{x_{IRDR_i}}{\overline{X}_{IRDR}} \right| \quad (2)$$

LIN_i is the local index of dissimilarity, which makes it possible to define by what specific dissimilarity ach country *i* contributes to the formation of the total index of dissimilarity *IN*. We use this adjustment to reveal the differences in trends between human development and expected demographic development in a particular country. x_{ILR_i} represents the index of human development in the given country and $\overline{X}_{ILR}$ is the average index of human development for all countries of the world. The index of demographic development in the given country is denoted as x_{IRDR_i}, while $\overline{X}_{IRDR}$ is the average index of demographic reproduction for all countries of the world. Finally, n_i represents the number of inhabitants in the given country and *n* is the total number of the world's population.

The results of the total index of dissimilarity (IN) may be interpreted as follows. The index of dissimilarity indicates how many percentage points need to be redirected to achieve a complete agreement between the index of human development and the index of demographic development.

Spatial Entropy: The Decomposition of Global Inequality

We use the concept of the so-called relative regional differentiation (as applied, e.g., in works by Tsui, 1993; Novotný, 2004; Netrdová & Nosek, 2009; Doran & Jordan, 2013; *anon. authors*; Panzera & Postiglione, 2020). The concept expresses the share of individual regional levels in total inequality. Thanks to this, we can say whether the measured global differences are more formed by differences between continents or regions, or whether total inequality is primarily driven by differences between countries within regions (Appendix 3).

Just for this purpose, it is proper to use the Theil index (T) belonging to the group of generalized entropy measures. This index can be decomposed into within-group (W) and between-group (B) components. The Theil index, modified in this way, looks as follows (Theil, 1979):

$$T = \left(\sum_{i=1}^{k} \frac{n_i}{n} . \frac{x_i}{x} . ln \frac{x_i}{x} \right) + \left(\sum_{i=1}^{k} \frac{n_i}{n} . \frac{x_i}{x} . \sum_{j=1}^{n_i} \frac{n_{ij}}{n_i} . \frac{x_{ij}}{x_i} ln \frac{x_{ij}}{x_i} \right) = B + W \quad (3)$$

The symbol n_i denotes the population size in the region *i*, while *n* represents the total sum of populations of all regions, x_i is the value of the observed phenomenon in the region *i*, and *x* stands for the average of the observed phenomenon for all regions. The variable n_{ij} expresses the population size of the j^{th} subregion in the region *i*, while x_{ij} is the value of the observed phenomenon in the j^{th} subregion of the region *i*. The values of the Theil index vary within the interval $<0, \infty)$.

If we aim to determine the proportion of several hierarchical levels, we must apply the procedure of subtracting individual components. Concretely, if we examine the three levels – differences between continents ($^{share}T_{continent}$), differences between regions within continents ($^{share}T_{region}$), differences between countries within regions ($^{shareT}{}_{state}$), the calculations are as follows:

$$\begin{gathered} {}^{share}T_{continet} = B_{continent}/T \\ {}^{share}T_{region} = B_{region}/T - B_{continent}/T \\ {}^{share}T_{state} = 1 - ({}^{share}T_{continet} + {}^{share}T_{region}) \\ or\ {}^{share}T_{state} = W_{region}/T \end{gathered} \tag{4}$$

where.

$B_{continent}$ is the magnitude of differences between continents.

B_{region} is the magnitude of differences between regions.

W_{region} is the magnitude of differences within regions.

The following spatial dimensions are used in the study: (a) continents (intercontinental differences), (b) regions (inter-regional differences), and (c) countries (differences between countries = intra-regional differences). The exact categorization of countries into regions and continents, which is used in our analysis, is shown in Appendix 3.

Results

The Evolution of Human and Demographic Developments and their Dissimilarities Over Time

Interrelations between the sub-indicators included in the indicators of human development and demographic reproduction show relatively considerable stability over time (Table 2). In 1970, the correlation coefficient reached a high value of 0.75 or more in half of the cases, while in as many as two-thirds in 2020. This is a primary indication of growing interconnectedness between the dimensions of human and demographic developments.

The mean global values in the components of human and demographic developments demonstrate quite a clear growth trajectory (Fig. 1). The fertility index and the mortality index show an analogous evolution. However, this does not apply to the individual components of human development. The inequality index is increasing very slowly. It even decreased between 2010 and 2020, which means an increase in global disparities measured by the Gini coefficient for income as well as the gender inequality in that decade. The income index and the educational index have developed in congruence, but their partial values tend to lower the total index. On the contrary, the index of health and nutritional conditions grows very dynamically and is always above the total index values.

Increasing values of the index of human development and that of demographic reproduction between the years 1970 and 2020 are evident also from a spatial perspective. Low values within the blue intervals are increasingly less represented over

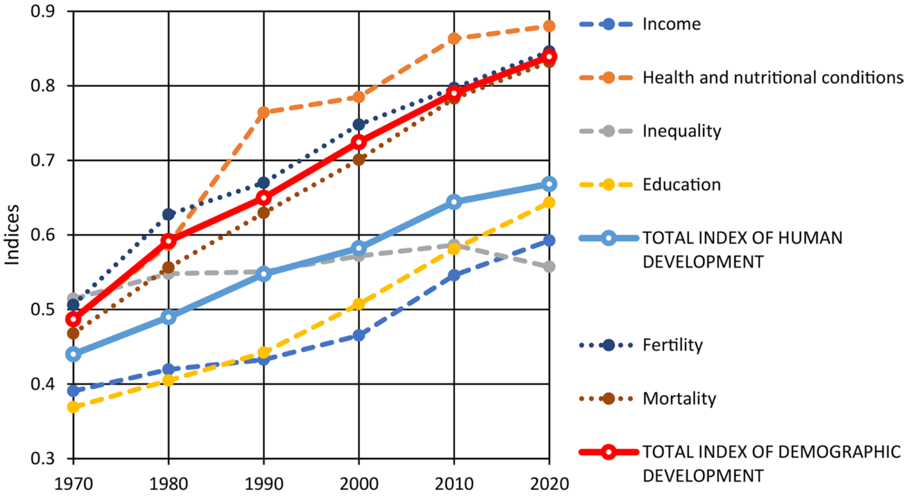

Fig. 1 Components of human development and demographic development. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

time (Figs. 2 and 3). While in 1970 the index of human development was below 0.5 in 98 countries (i.e., 68% of the world's population), in 2020 it was below the given value only in 31 countries – 9% of the world's population (Table 3). The increase in the average value of the index is accompanied by a decrease in absolute variability measured by the standard deviation. It is also manifested in the relative reduction of differences between countries (values of the coefficient of variation). An analogous situation can be observed in the index of demographic reproduction, although the initial values of absolute variability (measured by the standard deviation) and those of relative variability (measured by the coefficient of variation) were somewhat higher (Table 4).

An effective way to measure the relation between rate of human development and demographic behavior is provided by the index of dissimilarity, which is also suitable for measuring non-linear trends. The key finding is a decline in dissimilarity between the level of human development and that of demographic development. This is a relatively fundamental decrease (Fig. 4). We present several alternatives to the index of dissimilarity. The alternatives differ from each other in terms of which dimensions or partial indicators are incorporated in the calculation of both development indices.

All alternatives demonstrate a decrease in dissimilarity, but from different maxima and at varying rates of decline. We also simulated the inclusion of net migration; in this case, the index of dissimilarity is higher. For example, it reached a value of 0.22 in 1970. It means that nearly 22% are missing in achieving absolute (i.e. 100%) similarity between human and demographic developments ("no-migration" curve). In 2020, the index of dissimilarity was 0.1, meaning that both indices "fit" at 90%. If migration had been included, dissimilarity would have been only around 0.16–0.18 in the 1970 s and 1980 s ("with migration" curve). It then decreased continuously to a value of 0.08

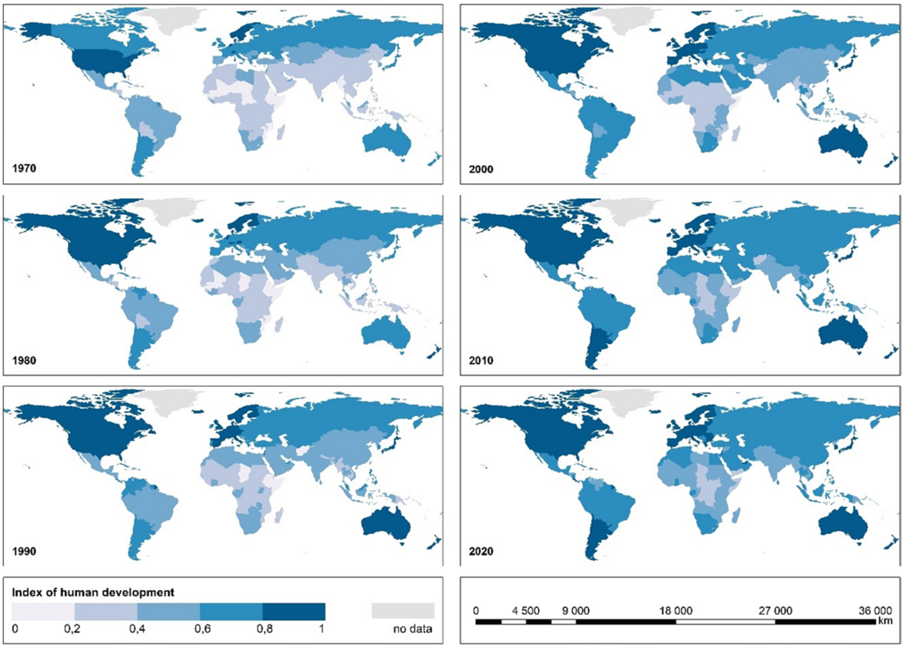

Fig. 2 Index of human development, 1970–2020. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

in 2020. The inclusion of migration thus affects global dissimilarity, and as expected, indicates that natural change and migration are two relatively separate phenomena.

If, in the fertility dimension, we do not use teenage fertility in the 15–19 age group as a proxy for fertility timing and instead use only the total fertility rate as a proxy for quantum (intensity), maximum dissimilarity in 1980 attains 0.20 ("fertility quantum" curve, see further details in Discussion). Vice versa, if we use only the tempo indicator, the maximum in 1980 amounts to 0.26 ("fertility timing" curve). In 2020, the difference in dissimilarity between these two alternatives is already negligible. Likewise, population weighting does not markedly alter the results ("pop_weighting" and "without_pop_weighting" curves).

Local Dissimilarities – which Regions do Generate most from Global Dissimilarity?

The number of countries classified as outliers, meaning those with the so-called local index of dissimilarity considerably above average, decreases over time. This index was the highest in 1970 on average, mainly in European countries and parts of sub-Saharan Africa. However, this picture holds true only if net migration is not included in the model. If it is, the number of extreme values is lower, and average is also significantly lower. Overall, there has been a growing "match" between human development and demographic behavior (Fig. 5; Table 5).

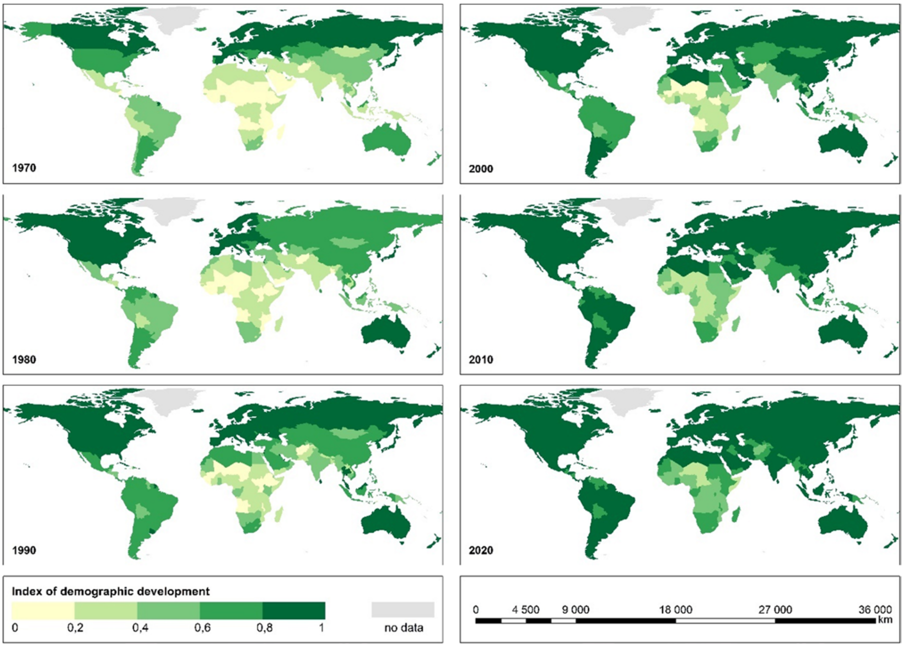

Fig. 3 Index of demographic development, 1970–2020. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

Table 3 Descriptive statistics of the index of human development, 1970–2020

		1970	1980	1990	2000	2010	2020
Number of countries with index	<0.00; 0.20)	24	18	5	2	1	0
	<0.20; 0.40)	47	41	37	31	24	19
	<0.40; 0.60)	52	53	52	51	46	42
	<0.60; 0.80)	40	45	50	55	57	58
	<0.80; 1.00)	10	16	29	34	45	54
Share of population in countries with index	<0.00; 0.20)	4%	3%	2%	1%	0%	0%
	<0.20; 0.40)	39%	37%	35%	21%	8%	5%
	<0.40; 0.60)	35%	32%	32%	33%	32%	32%
	<0.60; 0.80)	16%	15%	17%	31%	44%	47%
	<0.80; 1.00)	6%	13%	14%	14%	16%	16%
Average		0,49	0,59	0,65	0,72	0,79	0,84
Standard deviation		0,24	0,25	0,21	0,2	0,17	0,15
Coefficient of variation		48%	42%	33%	28%	21%	17%

Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

We have identified four basic types of countries by trajectory of dissimilarity over time: Type 1 – High dissimilarity all the time; Type 2 – Low dissimilarity all the time; Type 3 – High dissimilarity in the beginning and its later decline; Type 4 – Low dissimilarity in the beginning and its later increase. We present examples of countries falling into these types (Appendix 1).

Table 4 Descriptive statistics for the index of demographic development, 1970–2020

		1970	1980	1990	2000	2010	2020
Number of countries with index	<0.00; 0.20)	37	27	16	10	2	0
	<0.20; 0.40)	42	35	25	20	14	7
	<0.40; 0.60)	35	36	35	30	26	21
	<0.60; 0.80)	28	35	44	43	47	48
	<0.80; 1.00)	31	40	53	70	84	97
Share of population in countries with index	<0.00; 0.20)	8%	7%	4%	2%	0%	0%
	<0.20; 0.40)	35%	20%	17%	7%	4%	4%
	<0.40; 0.60)	26%	18%	19%	18%	15%	8%
	<0.60; 0.80)	10%	17%	22%	31%	32%	24%
	<0.80; 1.00)	21%	38%	38%	42%	49%	64%
Average		0,49	0,59	0,65	0,72	0,79	0,84
Standard deviation		0,24	0,25	0,21	0,2	0,17	0,15
Coefficient of variation		48%	42%	33%	28%	21%	17%

Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

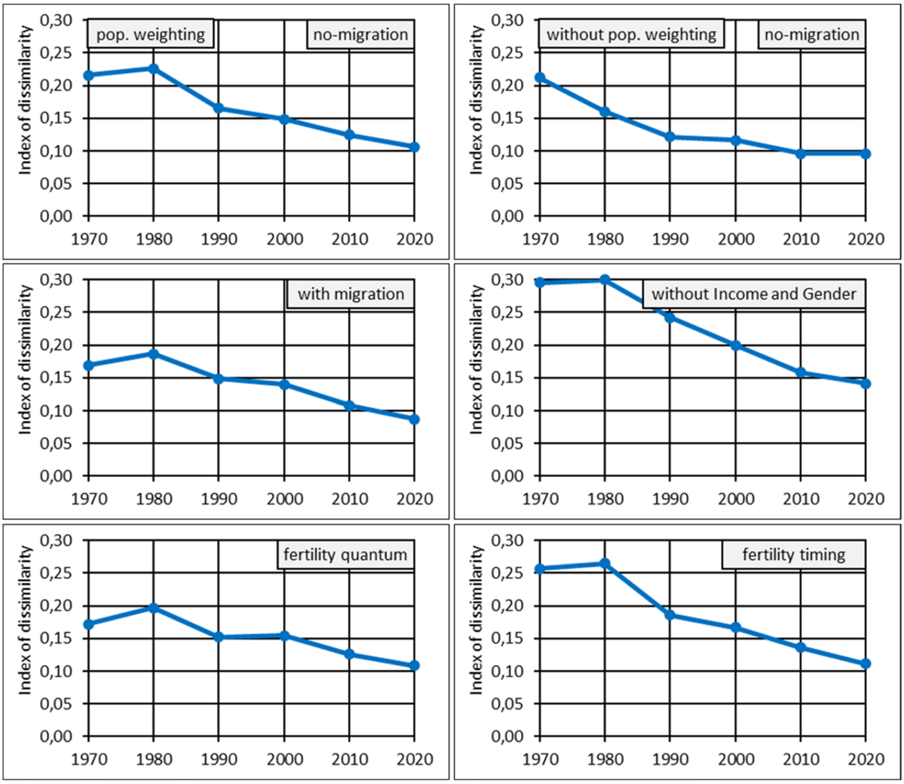

Fig. 4 Index of dissimilarity between the index of human development and the index of demographic development. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

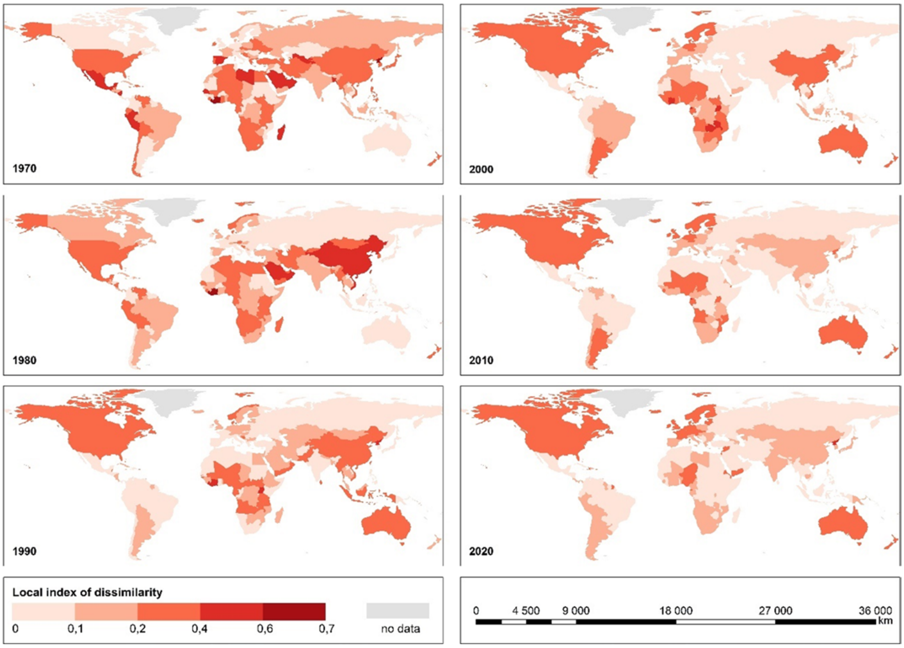

Fig. 5 Local-country indices of dissimilarity, 1970–2020. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

Table 5 Descriptive statistics for the local index of dissimilarity, 1970–2020

		1970	1980	1990	2000	2010	2020
Number of countries with index	<0.00; 0.10)	53	57	67	69	80	83
	<0.10; 0.20)	38	52	64	53	60	54
	<0.20; 0.40)	64	55	38	46	32	35
	<0.40; 0.60)	15	7	4	5	1	1
	<0.60; 0.70)	3	2	0	0	0	0
Share of population in countries with index	<0.00; 0.10)	10%	19%	34%	34%	44%	32%
	<0.10; 0.20)	26%	25%	14%	16%	42%	53%
	<0.20; 0.40)	59%	19%	52%	49%	15%	14%
	<0.40; 0.60)	4%	36%	1%	1%	0%	0%
	<0.60; 0.70)	0%	0%	0%	0%	0%	0%
Average		0,20	0,18	0,15	0,14	0,12	0,12
Standard deviation		0,14	0,13	0,10	0,11	0,09	0,08
Coefficient of variation		72%	72%	70%	75%	72%	71%

Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

Spatial entropy – the contributions of spatial dimensions to total inequality.

In most indices, there has been a significant decrease in the values of the Theil index since 1970. This means that variability decreased. If total spatial inequality expressed by the global Theil index is 100%, it can be decomposed into individual spatial dimensions and their contribution to total inequality can be calculated. Total inequality was decomposed into the intercontinental inequalities, inter-regional inequalities (regions inside continents), and intra-regional ones – i.e., inequalities between countries within the world's regions (Fig. 6). For both the income index and the educational index, intercontinental differences make up more than 50% of total inequality. On the contrary, the inequality index and the index of health and nutritional conditions more frequently show differences within continents−at the level of regions and, significantly, at the level of countries. Inequality in human development is generated primarily by differences between continents; the other two components play a much lesser role. With respect to total inequality in demographic development, on the other hand, differences between regions (inter-regional component) are far more pronounced, while the contribution of intra-regional differences is moderately decreasing. Over time, the contribution of intercontinental differences has increased, mainly due to fertility; since 2010, it has accounted for more than half of total inequality.

From a hierarchical perspective, some indicators show more and some less significant changes over time. If we understand the dominance of differences between continents as a first-order hierarchy, then in the case of demographic development this hierarchical dominance decreases, unlike in the case of human development.

To synthesize the results, we could conclude that in the case of partial indicators there is no stability over time, but on the contrary, there is a significant trend of change. The only exception represents the mortality index, in which the three spatial components have almost the same share in each analyzed year. The opposite example of an index whose trend has two different trajectories over time, is the index of health

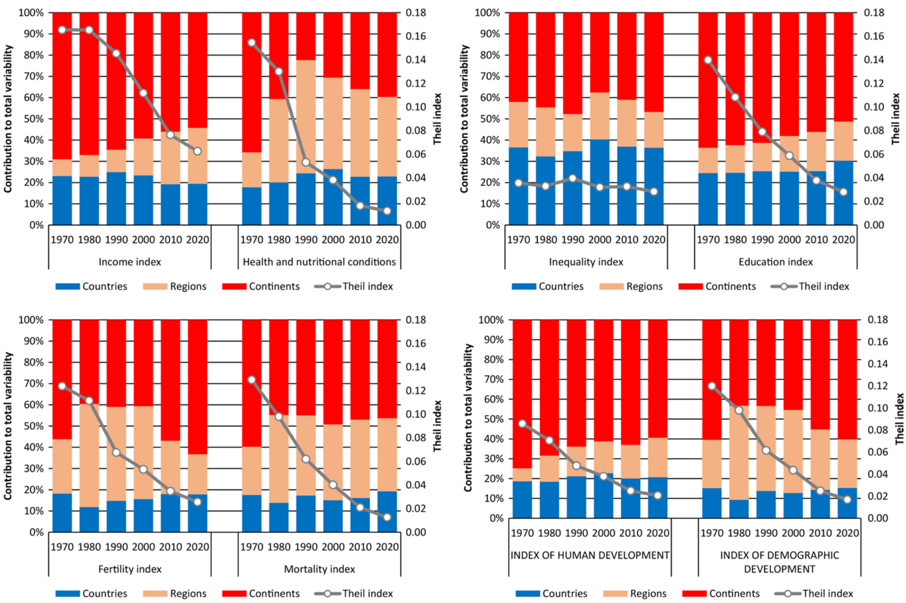

Fig. 6 Spatial components of total (global) inequality

and nutritional conditions. The sharp increase in inter-region differences stopped in 1990 and since that it has been decreasing slightly but significantly.

Discussion and Limits

The results confirmed that the similarity between human and demographic developments has been increasing over space and time. In this study, life expectancy was transferred from the index of human development to the index of demographic development. A certain risk is that life expectancy responds to both human and social developments, its increase is a direct consequence of social progress. However, this relation may not always be straightforward. Life expectancy can have a "life of its own". Besides the COVID-19 pandemic (Aburto et al., 2022; Scholey et al. 2022), the HIV epidemic can also serve as an example. With the decline in life expectancy, particularly in African countries (May & Ingle, 2011; Slogrove et al., 2019; Doan et al., 2022), the average quality of life there may have decreased, but the progress of human development as such has not stopped. Of course, as the Socio-demographic index shows, the tightness between health characteristics and the data on the economy or education is strong (Lancet 2019). The gradually spreading health and epidemiological transitions (Omran, 1971) in developing countries has its driving forces. It is likely that the health and mortality factors that also influenced the human development index contributed most to the reduction of dissimilarity. In the first place, these were probably mainly components within the Income index and the Health/nutrition index. These were the first, primary prerequisites for improving health and increasing infant and total mortality in developing countries, spreading gradually from the third world countries to the poorest 4th World countries. Later purely social and cultural factors began to play a more significant role. Simply put, first it was necessary to alleviate hunger, improve hygiene and build the first modern hospitals that would cover the needs of the majority in population. Only then could a decrease in female deaths due to a (decreasing) number of births and, with it, deaths of infants, be observed.

Greater, though still limited, "creative" design possibilities may be found for the index of human development. However, our results document that various combinations and (non)inclusion of components or partial indices do not yield fundamentally different outcomes – except for cases when the dimensions of income and gender are not incorporated. Without them, dissimilarity would have reached as much as 30% in the 1970 s and 1980s. This is quite a surprising result, which probably has an explanation in the population dynamics at the time. Around 1970, the demographic revolution took place on several continents, primarily in Asia and Latin America (Pavlík, 1980; Caldwell & Caldwell, 1997; Duda-Nyczak, 2021). It was precisely there that the hotspots of dissimilarity were located, including several populous countries – such as India, Indonesia or Mexico. We could talk about a two-way process of demographic transformation. In 1970, 56% of the world's population lived in countries with the index of demographic reproduction within the interval of $<0.25; 0.5\geq$. On the contrary, in the countries of the "developed West", the first demographic transition had already finished, and the second demographic transition began to manifest. By 2020, most countries in the world underwent the first demographic transition and the second demographic transition spread outside Europe and North America. Nevertheless, its global impact has been restricted and the universality of this conceptual model questioned (Coleman, 2004).

Can the results be more significantly influenced by how many, what, and in which way partial indicators are incorporated into the synthetic indices of human and demographic developments? Demographic development−principally (but not only) in association with the second demographic transition at the level of selected countries−can be expressed in a highly sophisticated manner; for example, through attitudinal and behavioral indices (Brzozowska, 2021). There are data for health life expectancy that describe health status better than conventional mortality indicators. So far, this life expectancy has been calculated chiefly for developed countries (e.g., Doblhammer, 2001; Yong & Saito, 2009). For calculations in this study, covering nearly 200 countries and half a century, even estimates are completely unavailable. The difference between fertility quantum (intensity) and fertility timing is a possible source of uncertainty and analytical risk as well. The total fertility rate is a transversal (annual) indicator, very suitable for measuring the intensity of the demographic process, but it can be influenced by changes in timing. This means that, for instance, if births were postponed during an economic crisis or a pandemic, the total fertility rate dropped. However, births are later caught up, what is called recuperation (Hašková, 2007; Frejka and Giete-Basten 2016).

A comparable situation occurred with the total fertility rate in former socialist countries after the fall of the Iron Curtain. This rate sharply declined to as low as 1 child per woman in some countries at the turn of the millennium. But generational (longitudinal) indicators show a less steep decline (Sobotka, 2011; Myrskylä 2013). There is also the opposite situation−earlier entries into motherhood may temporarily boost the total fertility rate, though after two or three years, it returns to its original or even lower level. Examples include pronatalist measures during the communist era (Monnier, 1990). The increase in birth rates in the countries of the so-called Mexican-Japanese type of demographic revolution after World War II is likely an analogous case (Reher & Requena, 2014). Anyway, for the set of countries since 1970, there is no better indicator than the total fertility rate; long-term trends can generally be well characterized by it. If we evaluate the similarity of demographic and human development in the last 5 decades, we must realize the following: In a large part of developed European countries, since the 1960 s, the second demographic transition has been taking place simultaneously with the first demographic transition in Latin America or Asia. This undoubtedly has an impact on the results of our analysis, but there is also a deeper theoretical perspective behind it. The declining fertility curves in northwestern Europe, together with the short-term increasing and then steadily decreasing fertility curves in the most progressive group within developing countries (e.g. Latin America), occurred in two different social and demographic contexts, the conditions of SDT and demographic transition in the latter case. And in addition, there was a “conserved” total fertility together with young fertility profiles in the entire communist bloc.

As we postulated in the Introduction, the measuring components of total inequality can help to uncover patterns of hierarchization in the development of the socio-economic and demographic systems, for instance in line with the theory of stages. An example of the decreasing importance of continents in terms of hierarchy can be considered index of education. The data demonstrates that their importance of intercontinental differences and therefore the vertical template of hierarchy is less valid than 50 years ago. The opposite case is the index of health and nutrition. Here the vertical hierarchy (indicated indirectly through differences) is strengthened from countries to higher continental level, which as a whole are virtually moving away from each other.

The major limit of the study is that we don’t have enough data to express demographic development through indicators of marriage or divorce rates. Therefore, we had to stick with fertility. The TFR has its drawbacks, such as volatility over time. Let’s admit that in the long run this does not play such a significant role and changes in timing will not significantly affect the results. However, the question stays whether the quantum or intensity, i.e., the number of children alone expresses demographic development, or whether this should be compared with human development. From a certain point in human development, the TFR does not actually decrease. Simply put, fertility may no longer be a sign of progress in terms of human development (e.g., Billari & Esping-Andersen, 2015; Goldscheider et al., 2015). Indeed, interpretation of fertility-mortality index as demographic development may be misleading in contemporary stage of the World´s development. On the other hand, this is only a relatively small segment within the temporal and spatial development since 1950. We simply could not leave out the development in OECD countries and/or post-socialist countries from the analysis.

To conclude the discussion, we present three case studies of countries that showed high values of the local index of dissimilarity (hotspots of dissimilarity) in the observed period: China, Spain and North Korea. Their development illustrates different mechanisms of the emergence of a discrepancy between demographic development and the level of human development in different institutional and political-economic contexts. In China, only a slightly increased level of dissimilarity was recorded in 1970, which, because of the introduction of the one-child population policy, increased significantly from 1980 and persisted until approximately 2000. At the then level of income and education, such a rapid decrease in fertility stood for an exogenous intervention in demographic development. At the same time, however, the decline in fertility intensity partially contributed to the improvement of the health and nutritional conditions of the population, which was reflected in the growth of the relevant index. At the end of the monitored period, there is a gradual decrease in dissimilarity due to economic growth and increased educational levels, which led to greater alignment of demographic and human development.

In 1970, Spain was among the countries with the highest values of the local inequality index. Despite the low values of the income index and significant inequalities, its population was relatively advanced from a demographic point of view, with low mortality and stabilized fertility. After the end of the dictatorship in 1975 and entry into the European Union in 1986, there was a significant increase in all components of the human development index. This development led to a gradual reduction in inequality, which practically disappeared by 1990. The subsequent slight increase in the local index was mainly related to the slower growth of the education index compared to the most developed countries.

North Korea has consistently demonstrated high local inequality index throughout the period under review. The main reason for this was a significant lag in human development despite relatively less adverse demographic characteristics. Between 1970 and 1990, there was a slight improvement in health and nutrition conditions, while other components of the human development index stagnated. The collapse of the Soviet Union and the disruption of trade ties were followed by an economic downturn, which was reflected in a worsening health situation and an increase in mortality. However, in the following period, with mortality stabilising and the persistence of low income and inequality indices, exacerbated by UN Security Council sanctions since 2006, local inequality has increased again.

Conclusion

To conclude, the relation between human and demographic developments is difficult to measure. This is analytical challenge, namely for several reasons that represent the crucial limitations. Two of them are probably the most important. First, demographic development – the level of demographic reproduction can be understood as part of human, social development, or, alternatively, social and demographic developments together as a part of overall human development. However, the demographic dimension has a special status and that is why we have treated it separately. Unlike wealth, access to drinking water or gender issues, people have a direct impact on demographic reproduction. Of course, mortality is less directly influenced by individuals than the number of their children, inter-birth intervals or the age at entry into parenthood. Thus, if the mortality component is removed from the model, dissimilarity reaches almost 40%. The highest local dissimilarity values are then found at the opposite poles of the spectrum – in Africa, but especially in Europe, namely to the east of the Iron Curtain. Here, human development did not go hand in hand with fertility, which was at a higher level due to pronatalist, sometimes radical, measures – for example, in Romania (Sobotka et al., 2019). We point out that the dissimilarity index is not only measure to be used in such a kind of study, however, but its ease of interpretability is also its greatest advantage.

As for further research, the main challenge seems to be how to deal with the fact that in an increasing number of countries the direct link between demographics and human development no longer works. One way would be to simply exclude countries above a certain level of human development, for example somewhere near the level at which countries would fall into the OECD group of countries, based on their human development index. This solution also has its drawbacks, because these countries are also part of the global demographic system. Unfortunately, given by the lack of data, we are unable to develop a more sophisticated indicator that would characterize demographic developments in greater detail and at the same time cover decades and the entire set of countries.

Explaining the differences in the contribution of the spatial levels in partial indexes appears to be quite challenging. We have only attempted a relatively simple typology. Its expansion in further research would be desirable. At the same time, it would be appropriate to uncover the background of the differences through a deeper socio-economic and demographic analysis, which is, however, a highly multidisciplinary task. If only a few representatives of each type were selected, it might be possible to use better, more sophisticated indicators in both main dimensions. In the demographic dimension, for example, tempo and parity adjusted fertility rates and longitudinal rates could be used for several countries. Finally, we see the potential of our approach also in the field of population forecasting. Modelling dissimilarities can be a starting point for creating future alternative scenarios. This means, we see here a possible contribution to the models that the team around W. Lutz in IIASA and Vienna Institute of Demography (later in Wittgenstein Centre for Demography and Global Human Capital) has attempted in population projections in the last roughly 20 years, i.e. modelling also the convergence/divergence in social and population trends using shared socioeconomic pathways, linked to education and also to climate change and other aspects. One of the aspects they have dealt with is the leveling or, conversely, the continuing heterogeneity across regions of the world, different in respect pathways. And this is precisely the area where our study intervenes, where the knowledge already gained or further gained can contribute to projections of the future World demographic and social developments in the context of its spatial variability. So far, any study has not projected future global and local dissimilarities as such. This analysis might be a good starting point.

We believe that despite several, mostly objective limitations, our study brings a relatively large amount of new empirical knowledge, processed in a new way. We have developed an original index of human development. Moreover, we dealt with a set of 195 countries as well as quite a long period − from 1970 to 2020. A large amount of data was processed. Alternative calculations were prepared to show the impact of different subdimensions on the overall results. Although there are studies that have tried to link human (social) and demographic developments, they have not worked to such an extent with spatial approaches and statistics. In such a detailed form with the design of original index of human development, this study is one of the few to quantify the contributions of different spatial levels to overall global inequality. The results of the study show that it requires a very comprehensive approach. Measuring these phenomena brings several pitfalls. Discussion in population studies can, for example, provoke the (non)inclusion of migration in indices that try to capture the level of demographic development. The results of the study should also be of interest to UN statisticians and other experts who are looking for new approaches to measuring human development. The perspective of demography and population geography proves to be very beneficial, and geostatistical modeling proves to be almost irreplaceable in this field as well.

Appendix

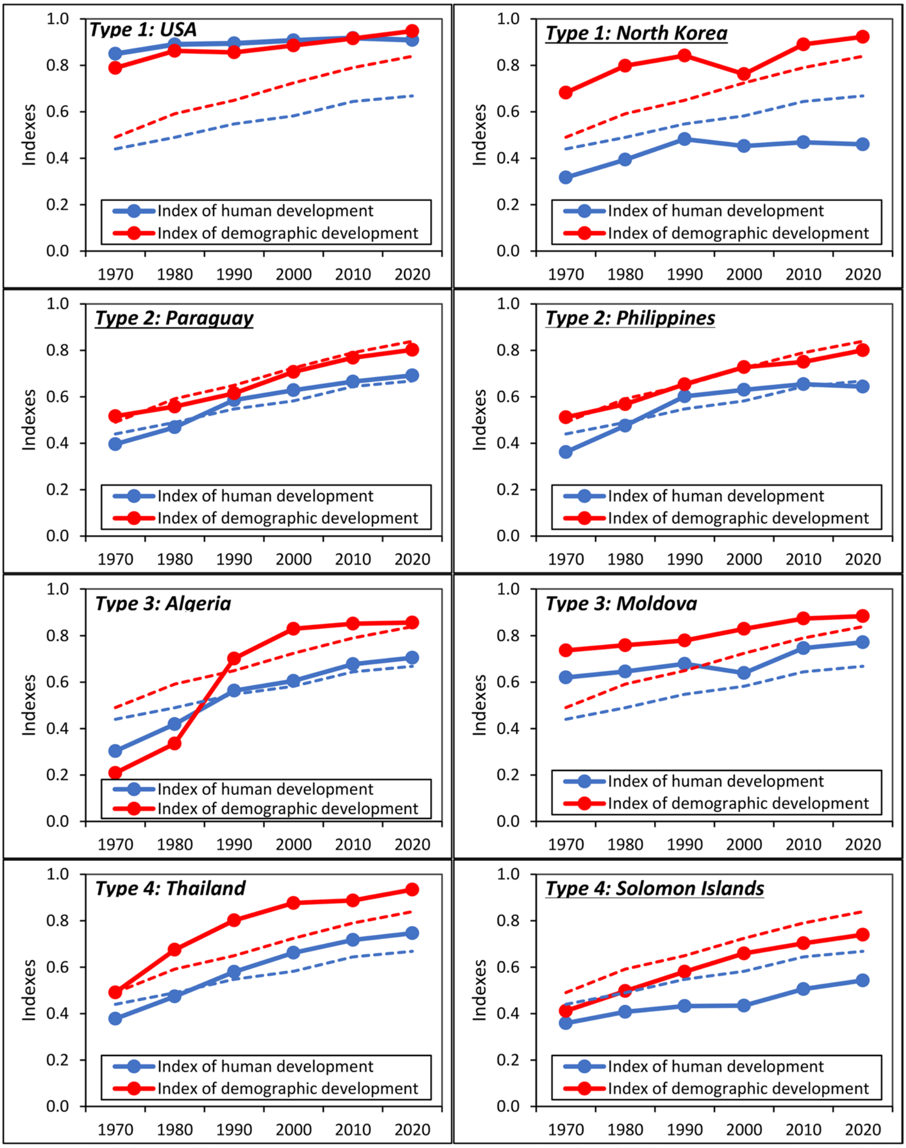

Fig. 7 Index of human development and index of demographic development from 1970 to 2020 in eight selected countries. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations. *Note:* Dashed lines represent global averages; Type 1: High dissimilarity all the time; Type 2: Low dissimilarity all the time; Type 3: High dissimilarity at the beginning and later decline; Type 4: Low dissimilarity at the beginning and later increase

1970	Model 1				Model 2				Model 3			
Dependent variable:	Index of demographic development				Fertility index				Mortality index			
Independent variables:	Subdimensions of social development				Subdimensions of social development				Subdimensions of social development			
R	0,91				0,85				0,91			
R Square	0,82				0,72				0,83			
Adjusted R Square	0,82				0,71				0,83			
Sig.ANOVA	0,00				0,00				0,00			
Coefficients												
	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF
Constant	-0,09		0,25		-0,16		0,14		-0,01		0,89	
Income index	-0,04	-0,03	0,65	3,97	-0,16	-0,11	0,19	3,97	0,09	0,07	0,25	3,97
Environment index	-0,07	-0,05	0,35	2,94	-0,04	-0,03	0,72	2,94	-0,10	-0,08	0,13	2,94
Health and nutritional conditions index	0,49	0,52	0,00	3,10	0,61	0,55	0,00	3,10	0,36	0,42	0,00	3,10
Education index	0,37	0,24	0,00	4,01	0,42	0,24	0,01	4,01	0,33	0,24	0,00	4,01
Inequality index	0,38	0,22	0,00	1,92	0,42	0,21	0,00	1,92	0,33	0,21	0,00	1,92
Spatial interaction index	0,03	0,03	0,54	1,59	0,02	0,01	0,80	1,59	0,04	0,04	0,34	1,59

1980	Model 1				Model 2				Model 3			
Dependent variable:	Index of demographic development				Fertility index				Mortality index			
Independent variables:	Subdimensions of social development				Subdimensions of social development				Subdimensions of social development			
R	0,92				0,86				0,92			
R Square	0,84				0,74				0,84			
Adjusted R Square	0,83				0,73				0,84			
Sig.ANOVA	0,00				0,00				0,00			
Coefficients												
	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF
Constant	-0,07		0,32		-0,19		0,08		0,04		0,48	
Income index	0,00	0,00	0,96	4,99	-0,18	-0,13	0,16	4,99	0,19	0,17	0,01	4,99
Environment index	-0,10	-0,08	0,16	2,96	-0,10	-0,07	0,33	2,96	-0,09	-0,08	0,13	2,96
Health and nutritional conditions index	0,41	0,43	0,00	3,78	0,45	0,39	0,00	3,78	0,38	0,44	0,00	3,78
Education index	0,39	0,26	0,00	4,93	0,56	0,31	0,00	4,93	0,22	0,16	0,02	4,93
Inequality index	0,43	0,26	0,00	2,04	0,59	0,30	0,00	2,04	0,27	0,18	0,00	2,04
Spatial interaction index	0,02	0,02	0,63	1,51	0,04	0,03	0,58	1,51	0,01	0,01	0,88	1,51

1990	Model 1				Model 2				Model 3			
Dependent variable:	Index of demographic development				Fertility index				Mortality index			
Independent variables:	Subdimensions of social development				Subdimensions of social development				Subdimensions of social development			
R	0,92				0,87				0,93			
R Square	0,84				0,77				0,86			
Adjusted R Square	0,84				0,76				0,85			
Sig.ANOVA	0,00				0,00				0,00			
Coefficients												
	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF
Constant	-0,01		0,86		-0,03		0,78		0,00		0,97	
Income index	0,18	0,16	0,04	3,23	0,04	0,03	0,76	3,23	0,33	0,32	0,00	3,23
Environment index	-0,13	-0,12	0,04	5,86	-0,23	-0,17	0,01	5,86	-0,04	-0,04	0,49	5,86
Health and nutritional conditions index	0,36	0,33	0,00	3,30	0,27	0,21	0,00	3,30	0,46	0,46	0,00	3,30
Education index	0,40	0,27	0,00	4,51	0,60	0,36	0,00	4,51	0,19	0,14	0,03	4,51
Inequality index	0,26	0,17	0,00	2,46	0,41	0,24	0,00	2,46	0,10	0,08	0,10	2,46
Spatial interaction index	-0,03	-0,02	0,56	1,43	-0,03	-0,02	0,70	1,43	-0,03	-0,03	0,48	1,43

2000	Model 1				Model 2				Model 3			
Dependent variable:	Index of demographic development				Fertility index				Mortality index			
Independent variables:	Subdimensions of social development				Subdimensions of social development				Subdimensions of social development			
R	0,92				0,88				0,92			
R Square	0,85				0,78				0,85			
Adjusted R Square	0,84				0,77				0,85			
Sig.ANOVA	0,00				0,00				0,00			
Coefficients												
	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF
Constant	0,06		0,41		0,18		0,08		-0,05		0,40	
Income index	0,11	0,11	0,14	5,27	-0,13	-0,11	0,21	5,27	0,35	0,37	0,00	5,27
Environment index	-0,14	-0,12	0,03	5,43	-0,33	-0,26	0,00	5,43	0,06	0,06	0,31	5,43
Health and nutritional conditions index	0,51	0,44	0,00	3,27	0,48	0,36	0,00	3,27	0,53	0,52	0,00	3,27
Education index	0,44	0,33	0,00	3,74	0,74	0,48	0,00	3,74	0,14	0,12	0,09	3,74
Inequality index	0,00	0,00	0,04	2,36	-0,03	-0,02	0,06	2,36	0,03	0,02	0,06	2,36
Spatial interaction index	-0,02	-0,01	0,71	1,44	-0,06	-0,04	0,31	1,44	0,03	0,03	0,47	1,44

2010	Model 1				Model 2				Model 3			
Dependent variable:	Index of demographic development				Fertility index				Mortality index			
Independent variables:	Subdimensions of social development				Subdimensions of social development				Subdimensions of social development			
R	0,93				0,89				0,93			
R Square	0,86				0,79				0,86			
Adjusted R Square	0,85				0,78				0,85			
Sig.ANOVA	0,00				0,00				0,00			
Coefficients												
	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF
Constant	0,00		0,97		-0,03		0,76		0,03		0,65	
Income index	0,20	0,22	0,00	2,98	0,18	0,16	0,07	2,98	0,21	0,29	0,00	2,98
Environment index	-0,08	-0,08	0,12	6,21	-0,18	-0,15	0,02	6,21	0,02	0,03	0,61	6,21
Health and nutritional conditions index	0,64	0,50	0,00	3,47	0,71	0,45	0,00	3,47	0,58	0,54	0,00	3,47
Education index	0,30	0,26	0,00	5,69	0,45	0,32	0,00	5,69	0,14	0,15	0,04	5,69
Inequality index	-0,05	-0,04	0,41	2,31	-0,12	-0,08	0,14	2,31	0,03	0,03	0,50	2,31
Spatial interaction index	-0,06	-0,06	0,08	1,38	-0,14	-0,11	0,01	1,38	0,01	0,02	0,66	1,38

2020	Model 1				Model 2				Model 3			
Dependent variable:	Index of demographic development				Fertility index				Mortality index			
Independent variables:	Subdimensions of social development				Subdimensions of social development				Subdimensions of social development			
R	0,90				0,86				0,90			
R Square	0,81				0,75				0,81			
Adjusted R Square	0,80				0,74				0,80			
Sig.ANOVA	0,00				0,00				0,00			
Coefficients												
	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF	Unstand.	Stand.	Sig.	VIF
Constant	0,19		0,00		0,10		0,27		0,28		0,00	
Income index	0,19	0,25	0,01	3,35	0,25	0,26	0,02	3,35	0,13	0,23	0,02	3,35
Environment index	-0,06	-0,07	0,19	7,35	-0,11	-0,10	0,12	7,35	-0,02	-0,02	0,70	7,35
Health and nutritional conditions index	0,44	0,40	0,00	2,59	0,51	0,36	0,00	2,59	0,36	0,42	0,00	2,59
Education index	0,28	0,28	0,00	5,93	0,37	0,30	0,00	5,93	0,19	0,24	0,00	5,93
Inequality index	-0,03	-0,03	0,58	2,41	-0,10	-0,08	0,22	2,41	0,04	0,05	0,37	2,41
Spatial interaction index	-0,03	-0,04	0,37	1,40	-0,09	-0,08	0,08	1,40	0,03	0,04	0,32	1,40

Fig. 8 Testing the components of human development by explaining demographic behavior. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations; Yellow color - no significance or strong collinearity

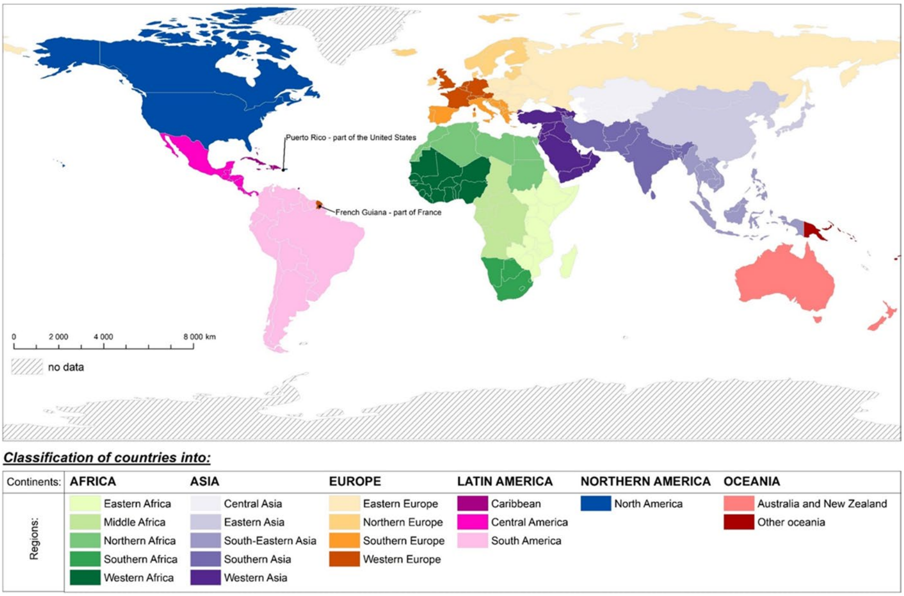

Fig. 9 Affiliation of countries to continents and regions

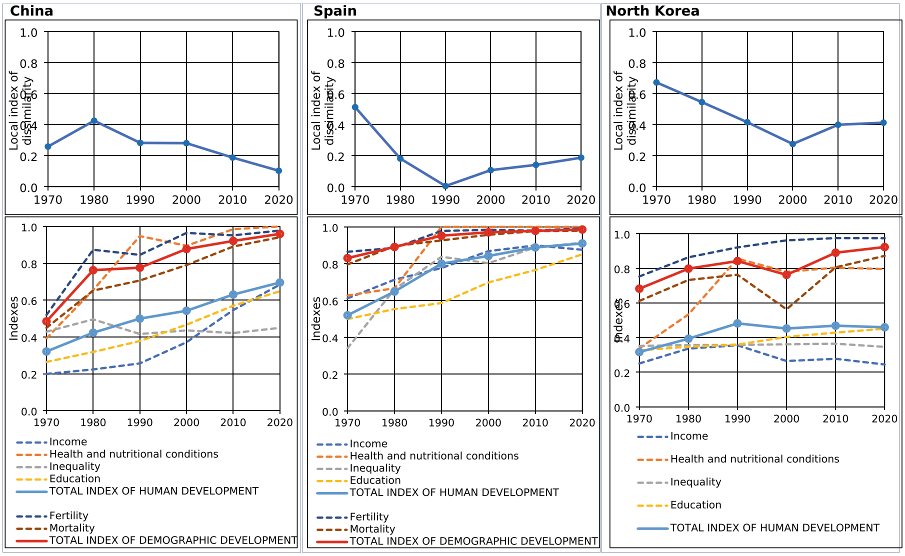

Fig. 10 "Hotspots of dissimilarity" - examples of countries with a large dissimilarity index. Sources: (Gapminder, 2023; United Nations, 2023a, 2023b; United Nations Procurement Division, 2023), authors' calculations

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Declarations

Competing interests The authors declare no competing interests.

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