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REGIONAL DISPARITIES AS A RESULT OF DIFFERENCES IN HUMAN CAPITAL AND INNOVATIVENESS ON THE EXAMPLE OF POLAND

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Abstract. Inequalities in human capital most often affect other spheres of life. It is people who create innovation, so the unequal distribution of human capital and innovation in the regions leads to development disparities between regions. This, in turn, is a force inhibiting the achievement of higher levels of prosperity at the national level. The existing studies mainly focus on the assessment of disparities in development between countries. Although understandings of mechanisms of regional disparities, i.e., assessment of how and whether disparities are disappearing or widening under current socio-economic conditions is crucial to economic stability and cohesion, the problem of determinants of development and the pace of development between regions has rarely been studied in the economic literature. The purpose of the article, therefore, is to show how quickly weaker regions are catching up with more developed regions and that regional disparities are mainly the result of uneven human capital accumulation. The authors wonder if human capital in the regions is used similarly to create innovation. Hence, they examine the rate of development of these two relationships. The research: (1) determines the pace of development and adjustment processes by using the dynamic time warping method, (2) discovers if human capital is the main driver of regional disparities and is fully utilized in the creation of innovativeness.

Keywords: regional disparities, historical and geographical accumulation, human capital, innovativeness, socio-economic growth.

JEL Classification: E24, J24, J40, O15, O30, R15.

Introduction

Spatial inequality is defined as an inequality in a socio-economic area in terms of geographical units. It is related to the greater openness of economies, globalization, and technological changes. Human development has so far been understood as producing as many goods and services as possible in the economy. This process strengthens the gap between cities and rural areas, between weaker and stronger regions, and between better and worse educated

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people. Today, this vision is changing. The development of human capital should be balanced to achieve the highest possible level of human life satisfaction. Well-being is connected with a high degree of social integrity, but also environmental, territorial, and economic. It can be achieved by investing in human capital, which is the primary driver of development in today's world (Kanbur & Venables, 2007). Poor infrastructure endowment and human capital stock, especially the high employment rate in agriculture, are still visible in emerging economies (Ezcurra et al., 2007).

Human capital is a significant driver of regional growth. It provides insight into the degrees of regional disparity (Erdem, 2016). Growth effects between countries are primarily regionally polarized (Barrios & Strobl, 2009; Buck et al., 2021; Iammarino et al., 2019; Martin, 2001; Rodríguez-Pose & Tselios, 2009; Sycheva et al., 2019). The same is true for human capital, which is not symmetrically concentrated in regions within countries but is accumulated in growth cores and large cities (Karahasan & López-Bazo, 2013; Rodríguez-Pose & Tselios, 2011).

Polish regions still exhibit significant differences in human capital endowment. There is a visible division between the more developed West and less developed East of the country (Czyż & Hauke, 2011; Gorzelak, 2006; Gurgul & Łach, 2019; Opiłowska, 2019; Wielki et al., 2018).

Empirical papers proved that one of the drivers is the historical and geographical accumulation of human capital. However, there is pretty few of research concerning the regional disparities of human capital and innovation and the pace of adjustment processes between the least and the most developed regions. The regional level provides additional information on the specificity of economic development processes. Region-specific research considers several aspects of spatial differentiation: natural resources, geopolitical location, culture, human capital, and metropolization. This study's main objectives are: to define the pace of development and adjustment processes between human capital and innovativeness to assess to which extent human capital explains the regional inequalities. Our main hypothesis is that regional disparities are mainly due to inequalities in human capital and innovation. Faced with this hypothesis, we posed the research question of whether weaker regions can catch up to regions described as growth centers, and whether these adjustment processes depend on the historical and geographic accumulation of human capital described in the literature. To our best knowledge, this is the first application of dynamic time warping to estimate the development patch of human capital and innovativeness in the regions. Our work is an interdisciplinary study between two directly unobservable categories like human capital, innovation in the context of economic growth, and quality of life measurements. The study was carried out on the example of Polish regions. However, it can be easily generalized to developing countries of the former Eastern Bloc, which have been admitted to the European Union. The chosen time horizon of 15 years examines the context of accession to the European Union. The remaining part of this paper is organized as follows. Section 1 gives an overview of related literature. Section 2 describes the data and methodology used. Section 3 presents the results of the study. Section 4 discusses the empirical analysis and limitations of our research, followed by conclusions in the last section.

1. Literature review

The main precursors of the human capital theory of the 1960s are considered to be three authors: Mincer (1984), Schultz (1961), and Becker (1994). Their theoretical considerations and empirical research became the basis of human capital theory, which is still developed in the social sciences today. Human capital is a complex economic category that explains why technical progress through innovation is possible in some countries and not in others. The OECD's definition of human capital captures the essence of the issue. Human capital consists of knowledge, competencies, skills, and other attributes that enable an individual to build personal, social, and economic well-being (Healy & Côté, 2001).

Since human capital is the primary determinant of innovativeness, regional differences in innovation potential are, to no small extent, a derivative of the spatial distribution of human capital (Bronzini & Piselli, 2009; Rodríguez-Pose & Vilalta-Bufí, 2005). The process of historical and territorial accumulation of human capital is discussed in the literature. Distribution of human capital results from the cultural heritage, religion, geopolitical conditions, state institution quality, democracy, and investment in children (Abramson et al., 2001; Becker et al., 2020; Dittmar & Meisenzahl, 2020; Gawthrop & Strauss, 1984; Johansson, 2009; Piatkowski, 2018). Human capital clustering often occurs because people who have a high level of human capital concentrate on areas where their potential will be better utilized. Thus, human capital distribution manifests a spatial character (Fujita et al., 1999; Storper & Scott, 2009). According to the creative class theory (Florida, 2002), the highest level of human capital represented by high-class professionals is concentrated in large cities and smart cities with broad access to educational, health, sports, and cultural services. Simultaneously, this type of capital creates a creative environment and stimulates local growth, attracting talented people and financial capital (Abu-Rayash & Dincer, 2021; Mellander & Florida, 2007, 2021; Storper & Scott, 2009). This process expands the concentration of high-quality human capital and, according to some scholars, also improves the situation of those lower-skilled (Liu & Yang, 2021). Along with human capital, there occurs a concentration of business activity, which takes advantage of access to human resources (knowledge, experience), especially when it is relatively cheap for investors (Clark et al., 2002). Hence, there is an accumulation of the highest quality human capital that migrates from less developed regions in some areas. The process of such accumulation is associated with positive externalities resulting from population growth, knowledge input, and labor productivity. In areas where there is an outflow of human capital, we can observe the opposite processes caused by the region's material losses resulting from the loss of educated people (Faggian et al., 2019; Myrdal, 1957). A higher development rate occurs in regions with a friendly environment for the absorption and diffusion of innovation. However, innovation is not possible without knowledge and human capital (Friedmann, 1972). Therefore, a better understanding of the nature of regional disparities in productivity, income, or innovation can begin with analyzing the determinants of human capital's spatial distribution. New Economic Geography (NEG) has suggested a link between each economy's endowment with human capital and the spatial distribution of economic activity (Krugman, 1991). Higher quality human capital implies increased productivity, as well as regional diffusion of knowledge and technology. Regions with higher levels

of human capital, i.e., with highly educated and skilled human beings, have more significant benefits from technology diffusion (Arrow, 1962; Polasek et al., 2011). Development policy based on comparative advantages is proposed by Lin (2012) in New Structural Economics. The author believes that each country is characterized by a different quality of development and the same recipes cannot be used for all. It is necessary to consider endogenous conditions and create conditions for development and innovation by the state, also by providing access to financial capital.

Differentiation of regional development is consistent with Myrdal's theory of cumulative causality (1957) and polarization theories: e.g., Perroux's growth poles (1950), Hirschman's uneven development (1958), Friedman's core and periphery (1972), Storper's learning region (Storper & Scott, 2009) and Florida's creative class (Florida, 1995).

According to Statistics Poland (SP), innovation resulting from human capital is enterprises' ability to create and implement innovations and the actual ability to introduce new and modernized products, modified or new technological or organizational and technical processes. This definition was proposed by the Oslo Manual (OECD/Eurostat, 2018), an international methodological standard called the Oslo Manual. It provides guidance to OECD countries on a list of comparable innovation indicators.

The link between human capital and innovation stems from creativity and entrepreneurship as attributes of human capital. Hence, it is essential to undertake entrepreneurship education, especially in higher education, to teach students to think outside the box and encourage them to increase their human capital through various channels, not just through formal education (Li et al., 2018). Knowledge and the education system are critical in shaping a knowledge-based society and knowledge economy. The process of building a knowledge economy is complex and comprehensive, but no less necessary to reignite further pro-growth impulses (Melnikas, 2010). Researchers agree on the positive role of human capital in innovation and development. This is the case in both the business sector and regions. Researchers agree on the positive role of human capital in innovation and development. This is the case in both the business sector and regions. What is difficult to examine is the relationship between which human capital attribute has the most impact on raising innovation. It is indicated that it is in the case of companies, for example, experience, knowledge, training, and internal communication (Jardon, 2016). From a regional perspective, the education system, vocational training, pieces of training, and doctoral programs are important (Teslenko et al., 2021).

Many authors have demonstrated the positive impact of human capital on socioeconomic growth (Badinger & Tondl, 2003; Cuaresma et al., 2014; Di Liberto, 2008; Fagerberg et al., 1997). It seems intuitive that growth processes are greater the more innovative a country/region/company is. Thus, it is valuable to study the link between human capital and innovation as major components of human capital.

Such a study within European regions has already been conducted. One of them covers a long period (1850–2010) (Diebolt & Hippe, 2022), but is based on a small number of variables. Some studies consider a wider range of dates (Faggian & McCann, 2009; Pater & Lewandowska, 2015). However, what is lacking is a study at the regional level that comprehensively captures the widest possible range of characteristics describing human capital and innovation and comparing their development paths.

The developmental differences in Polish regions are partially due to historical and geographical legacies. Until now, in studies conducted in the areas of distribution of wealth, poverty, voting preferences, and worldview (conservative, liberal), a division is evident between the more developed Western Poland often called Poland A and the less developed Eastern Poland called Poland B. The system of democracy and education, or the quality of public institutions affect the degree of development of the country. Unfortunately, at the end of the 18th century, as a result of the weakness of the above, Poland sank into a slump and lost independence for 123 years (1795–1918) (Backhaus, 2019). The Polish occupiers were: Russia (occupying Eastern Poland), Prussia (occupying the West), and Austria-Hungary (occupying the South).

Until now, traces of this division can be seen in the spatial differentiation of socio-economic development or education performance (Bukowski, 2019; Churski et al., 2021; Grosfeld & Zhuravskaya, 2015). Furthermore, warfare during World War II, and forced migration during or after the war, was particularly prominent in Poland. Hence, for example, one notices greater investment in intangible assets such as education in the west of the country, where there was a predominantly immigrant population from the eastern borderlands named Kresy Wschodnie (areas lost to Poland after World War II) (Becker et al., 2020).

As indicated, the impact of historical processes has already been studied in Poland. We, however, want to indicate how the trajectory of the development of human capital and innovation, i.e., the factors that, on the one hand, are the main factor of regional disparities and, on the other hand, a stimulator of regional development, has been carried out over the past 15 years. The take of study in methodological terms is being done for Polish regions for the first time and will bring an answer to whether indeed the distribution of human capital is responsible for regional disparities and whether it is currently being fully used to create innovativeness.

2. Materials and methods

2.1. Data source and variable selection

We examined 16 Polish voivodeships (administrative regions). Poland is an example of a developing country from the former Eastern Bloc. The first step contains assessing the potential of human capital and innovativeness and their dependencies after Poland acceded to the European Union in 2004.

In assessing the level of human capital, we adopted a composite index concept, which includes 120 (one hundred twenty) characteristics that reflect human capital formation according to an individual's life cycle. Accordingly, several subareas such as childhood, school period, working-age, and post-working age are distinguished within the index (7 characteristics for childhood, 33 for schooling, 76 for adulthood, and 4 for post-working age). The 76 variables within the Adulthood area were divided into smaller groups depicting essential aspects of human capital formation in adulthood, i.e., four variables – education, 5 – demographic potential, 36 – professional work, 5 – R&D and knowledge economy, 5 – entrepreneurship, 2 – social capital, 4 – leisure time, 2 – social exclusion, 11 – health. Twenty-eight

characteristics describe innovativeness. They represent six areas: firms' innovation, sales/exports of innovative products, foreign direct investment, inventiveness, the potential of science, and GNP per capita. To determine the most objective weights of individual characteristics, we used a composite index– TOPSIS, which consists of five independent base indices. It represents a multi-criteria approach (Chen & Hwang, 1992). We used the subjective method, equal and subjective weights (Greco et al., 2019), Hellwig's method (Hellwig, 1968), PCA (Abdi & Williams, 2010) and Mazziotta-Pareto (Mazziotta & Pareto, 2018). The steps of the procedure for creating the index are shown in Figure 1.

Multiple sources of data were used to build an index. The data sources included the Local Data Bank (LDB) of Statistics Poland (Polish abb. GUS), Eurostat, UNESCO, and other public. The study covers a 15-year time horizon (2004–2018). The first year was 2004, which corresponded with Poland's accession to the European Union and subsequently an initial state of human capital and innovation in Poland at the level of voivodeships.

Choice of variables:

Human capital is heterogeneous, which makes it difficult to measure. Human capital is heterogeneous, which makes it difficult to measure. Authors who have studied this development factor so far have used three distinct approaches to human capital valuation (Abraham & Mallatt, 2022; Folloni & Vittadini, 2010; Le et al., 2003):

1. the educational stock-based approach;
2. the cost-based approach, otherwise known as the retrospective method;
3. the income-based approach, otherwise known as the prospective method.

Each of these methods is subject to weaknesses, so the authors proposed a measure of human capital and innovation based on a synthetic index that captures a very broad range of characteristics. Our approach draws on the achievements of all the methods, so the set of diagnostic variables will also include those reflecting cost, income, education indicators,

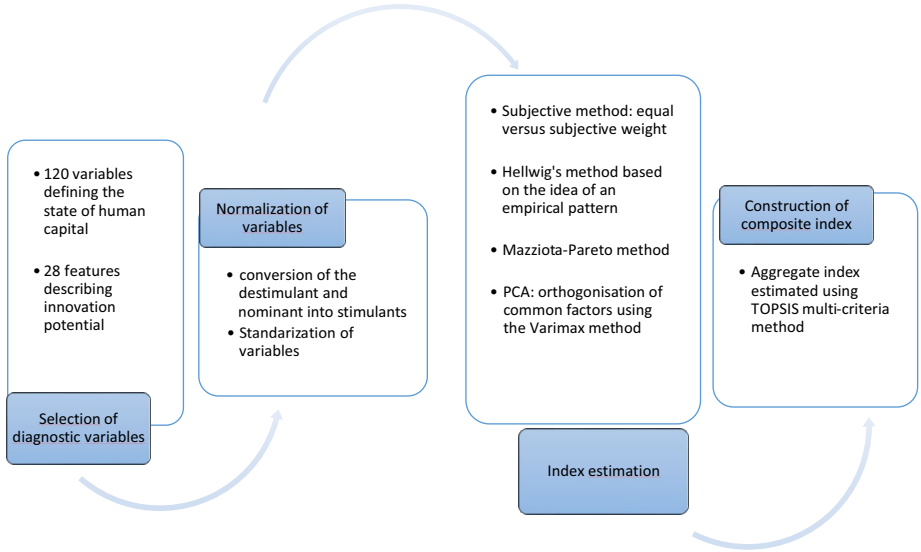

Figure 1. Algorithm of composite index construction (source: own elaboration)

or latent variables. It should be remembered that also the idea of a synthetic index is not free from flaws. Such measures are used by the European Union in assessing innovation (European Innovation Scorecard) or human capital (Knowledge Assessment Methodology). Our measure, however, maximizes the analytical utility of the main composite index, as the selection of features is performed by 5 independent approaches, which in effect form the main index based on an additional feature weighting strategy – TOPSIS. This allows for a very robust way of weighting the data. The subjective approach itself is based on the body of literature considering determinants of human capital and innovation, and a detailed description of feature selection is justified in the previous publication (Jagódka, 2021, pp. 67–100). Additionally, a detailed list of variables can be shared by authors on request. Moreover, the condition of human capital and the innovativeness of regions in Poland has already been described based on a synthetic index in an earlier publication (Jagódka & Snarska, 2021, 2023). The substantive selection of variables involved assigning each attribute a weight, understood as a share of a given variable in the synthetic index. The ordinal numbering of variables was proposed to ensure transparency of data and at the same time to enable classification of characteristics according to the adopted model of human capital formation during the life cycle of an individual, which can be schematically written using the symbol *X_ijz*, where *i* stands for individual stages of human life (childhood, school, adulthood, old age), while *j* is the number of a sub-area of research variables, *z* determines a two-digit number of a variable in its group. All features were selected based on the body of previous empirical and theoretical research. We created a very broad set of factors, and in building the composite index we used 5 independent feature weighting methods. This allowed us to objectify the results with no risk of an elimination or lack of representation of the variables. All features considered the regional level and therefore the specifics of development in the regions.

2.2. Spatial disparity modeling

We used dynamic time warping (DTW) to identify differences in human capital development and the region's innovativeness. DTW allowed us to specify the intertemporal rate of change in the analyzed indices.

Dynamic time warping was used to define the degree of intertemporal change in human capital and innovation in individual regions. The tool allowed for a comparison of human capital and innovation in individual voivodeships to the Mazowieckie, where Poland's capital is located, which is taken as a benchmark. It is also possible to estimate the average differences in Polish regions' development compared to Mazowieckie.

Dynamic time alignment is a statistical algorithm that allows measuring similarities or differences between time series and the speed of adjustment mechanisms. In the first step, the time series is divided into equal periods, e.g., consecutive years. The Euclidean distances between the initial points, i.e., the first year of observation for the first time series, and each of the years of observation for the second time series are determined. Of all distances, the smallest one is selected, and the year one is used as the reference. The Euclidean distances between all observations in the second time series and the second year of observation in the first time series, which is the reference, are then estimated. The algorithm is repeated until the reference points in the first time series are exhausted.

In a further step, the procedure is analogous, with the reference points coming this time from the second series. In the final step, a measure of similarity between the time series is estimated, which is the sum of the previously calculated minimum distances (Giorgino, 2009). A local distance measure is determined to compare the time course of human capital and innovation indices for two distinct provinces. The local distance measure is a function in the feature space Φ. The function values are relatively small when time series are close to each other and significant when they differ.

$$d : \Phi \times \Phi \to R \geq 0. \tag{1}$$

The local distance measure should be understood as a cost function. The optimal measure of similarity between time series for a given province concerning the benchmark province requires finding a suitable sequence of points to minimize the cost function using dynamic programming. In a general scheme, the first step of this procedure is to create a local distance matrix:

$$D_t = N \times M : x_n^i - x_m^B,\ n \in \left[1 : N\right],\ m \in \left[1, M\right], \tag{2}$$

where $M = 15$ and $N = 15$. The matrix constructed in this way reflects the distances between all pairs of elements of the human capital or innovation series in the province "i" and the reference province, marked with the letter "B". Next, the so-called warping path is determined, which runs through areas with the lowest cost and minimum distances. The path's shape affects the time series of the index under study concerning the benchmark index. It will therefore be a set of:

$$p = \left(p_1, p_2, \ldots, p_k\right),\ p_1 = \left(p_n, p_m\right) \in \left[1 : N\right] \times \left[1 : M\right] = \left[1 : K\right], \tag{3}$$

for which the first and the last points of the x^i, x^B indexes are matched, i.e., occur at the same point in time. Interpretation is that individual voivodeships in the examined period may differ from each other in the rate of development in terms of innovation and human capital. However, the first and last years in the sample are considered constant. Besides, the matching path is monotonic, which means no reversal of adjustment processes over time.

In terms of optimization, the development of voivodeships on the benchmark cannot occur too quickly. Human capital and innovation in a given province will not develop faster than the established benchmark, a specific reference for the path of development in individual years. The optimal path of distance from the pattern of development is the path of development with minimum cost. Dynamic programming algorithms are used to find it:

$$DTW\left(x^i, x^B\right) = \min\left\{D_p\left(x^i, x^B\right),\ p \in P^{M \times N}\right\}, \tag{4}$$

where $P^{M \times N}$ is the set of all possible matching paths.

3. Results

We used DTW to examine how the development path and adjustment processes of Polish provinces from 2004 to 2018 for human capital and innovation. Benchmarking is the capital region – Mazowieckie province that performs best. The development trajectories of other

provinces were just compared to the Mazowieckie province. The purpose of this is to demonstrate whether, under conditions of higher growth rates at the national level, development disparities within human capital and innovation within Polish provinces have narrowed.

The development differences between Polish voivodeships to the model region of Mazowieckie voivodeship are presented in Table 1. The closer the score to zero the better. This means that the level of development or adjustment processes of a given voivodeship to the Mazowieckie is proceeding rapidly, which is conducive to leveling out disparities.

The highest level of human capital development compared to Mazowieckie was recorded in Dolnośląskie, Pomorskie, and Małopolskie voivodeships. The greatest disproportions in relation to the benchmark were noted in Podkarpackie, Świętokrzyskie, and Kujawsko-Pomorskie voivodeships. Comparing the pace of human capital changes in Mazowieckie voivodeship, the best results were achieved by Dolnośląskie, Pomorskie, and Małopolskie. In contrast, Opolskie, Kujawsko-Pomorskie, and Podkarpackie achieved the worst results. Mazowieckie also grew faster than the other regions in terms of innovation potential. Małopolskie, Śląskie, and Dolnośląskie followed it in terms of the rate of innovation potential multiplication. The Łódzkie, Opolskie and Świętokrzyskie voivodeships had the slowest rate of change in innovation in relation to Mazowieckie.

The average level of innovation development with Mazowieckie as the benchmark was highest in Dolnośląskie, Małopolskie, and Śląskie. The most significant distance in innovation to Mazowieckie was observed in Warmińsko-Mazurskie, Podlaskie, and Świętokrzyskie.

Table 1. Differences in the development of Polish regions in the field of the rate and level of human capital (HC) development and innovation (INN) in the years 2004–2018 in the Mazowieckie voivodeship (source: own elaboration. Calculations were performed using the R program)

Differences in development	The pace of development		Development level	
	HC	INN	HC	INN
Małopolskie	0.2027	0.1250	0.2990	0.4895
Śląskie	0.2796	0.1344	0.4245	0.5099
Wielkopolskie	0.3183	0.1967	0.2939	0.5562
Zachodniopomorskie	0.3268	0.2957	0.3385	0.8072
Lubuskie	0.3689	0.2638	0.5026	0.8672
Dolnośląskie	0.1295	0.1466j	0.2703	0.3746
Opolskie	0.4706	0.3138	0.3867	0.8491
Kujawsko-Pomorskie	0.4444	0.2821	0.5465	0.8676
Warmińsko-Mazurskie	0.3426	0.3263	0.4686	1.0486
Pomorskie	0.1982	0.1553	0.2814	0.6184
Łódzkie	0.3014	0.3331	0.3630	0.9193
Świętokrzyskie	0.4101	0.3128	0.6149	0.9887
Lubelskie	0.3726	0.2464	0.5151	0.8637
Podkarpackie	0.4328	0.1901	0.7222	0.6635
Podlaskie	0.3332	0.2570	0.4287	1.0150
Mazowieckie	0.0000	0.0000	0.0000	0.0000

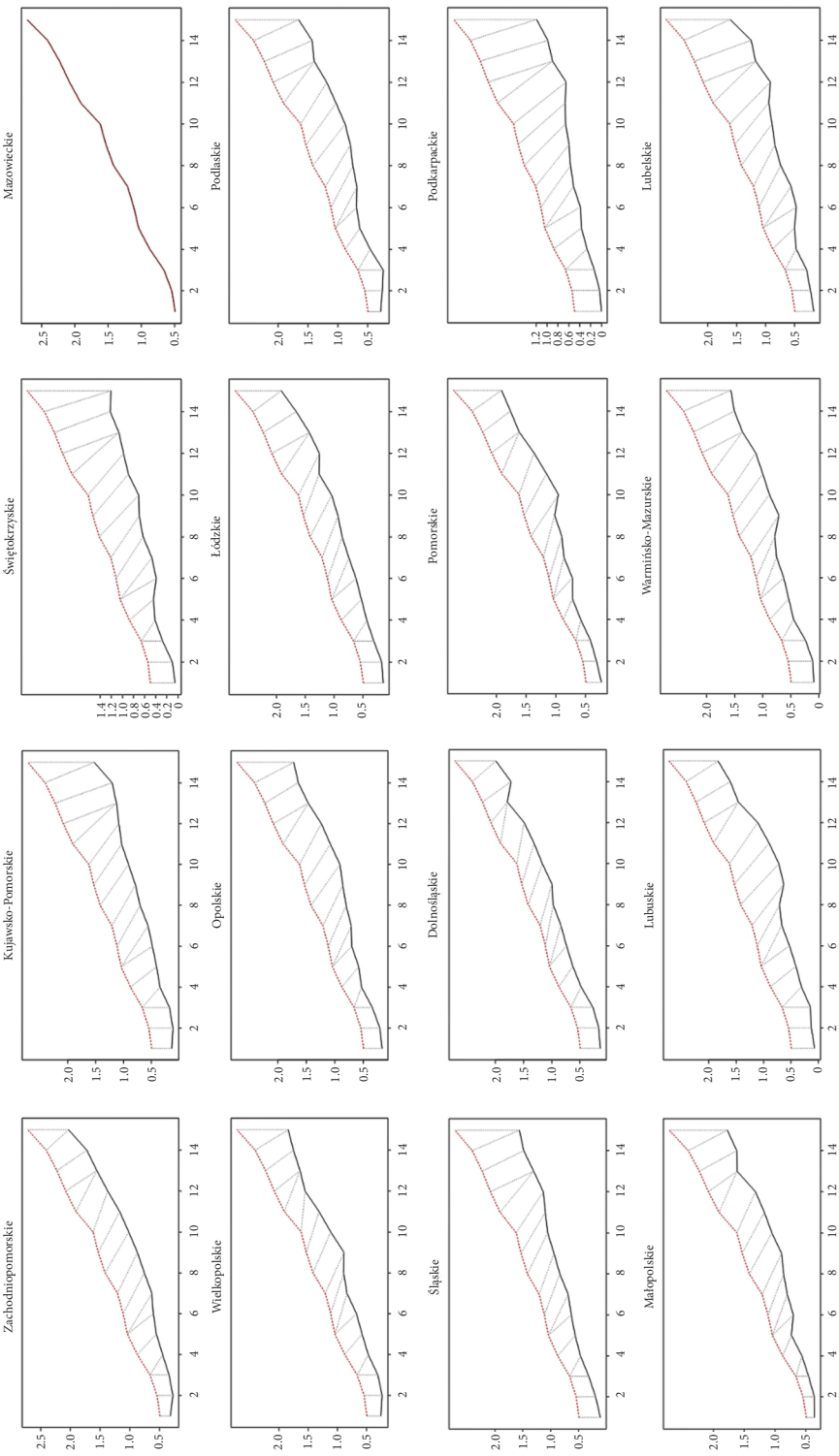

Figure 2. Disproportions in the development of human capital of voivodeships to Mazowieckie voivodeship in the years 2004–2018 (source: own elaboration. Calculations were performed using the R language. The vertical axis represents the value of the human capital index and the horizontal axis represents the period number from the sample (14 years))

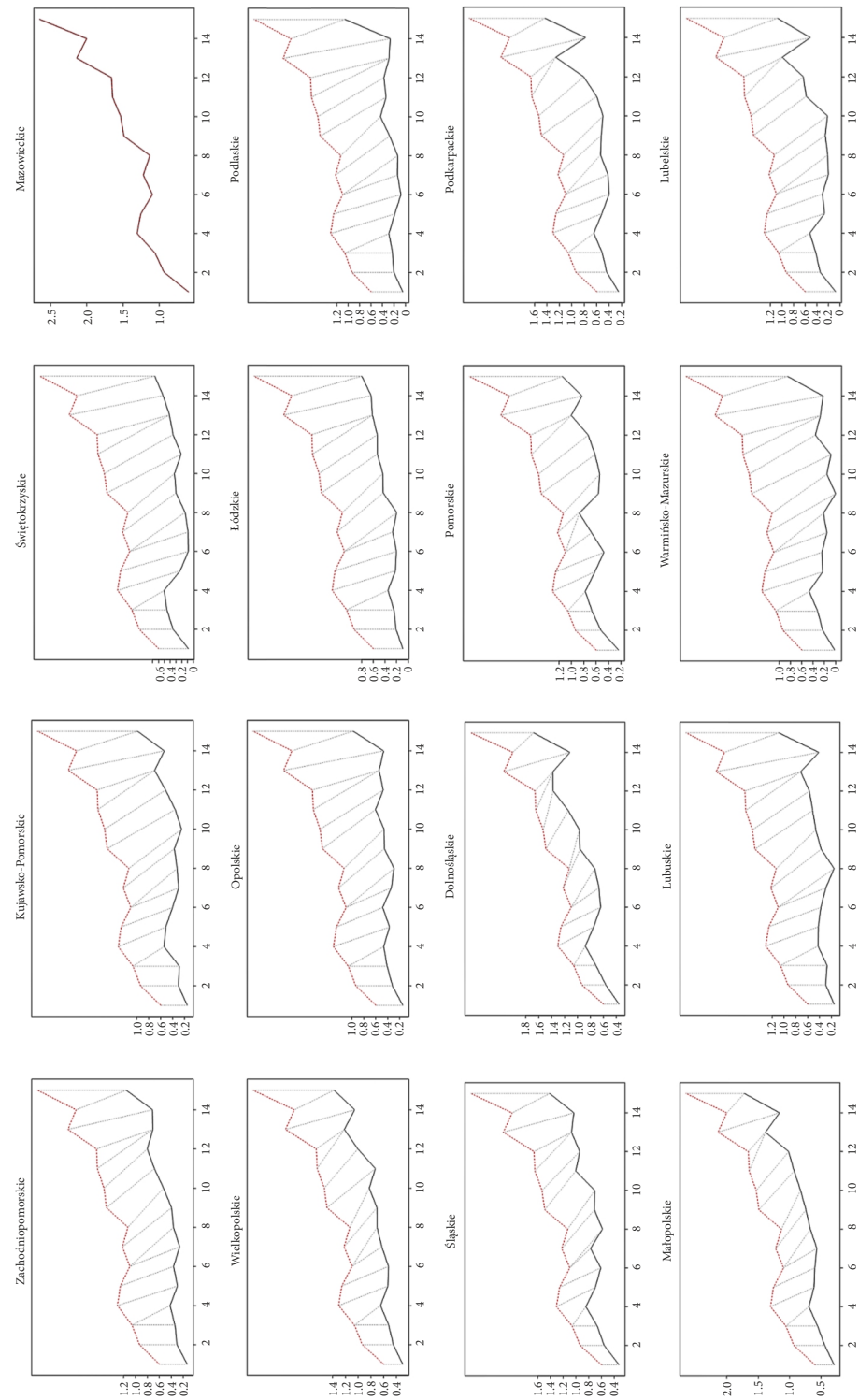

Figure 3. Disproportions in innovation potential of voivodeships to Mazowieckie voivodeship in 2004–2018 (source: own elaboration. Calculations were performed using the R language. The vertical axis represents the value of the innovation index and the horizontal axis represents the period number from the sample (14 years))

Observing Figures 2 and 3, one may state that the development disparities within human capital and innovativeness related to the benchmark voivodeship not only did not decrease, but also increased. While in the initial period of the study,. the pace of development was similar, in the following years. Mazowieckie was "running away" from other regions. A faster pace of Mazowieckie's innovation development and its divergence from the other voivodeships was observed than in the case of human capital. The higher state of human capital occurred in regions recognized to have large urban centers, where metropolization processes have occurred. Research gave no basis for stating that the European cohesion policy implemented from 2004–2018 in Poland has reduced regional disparities in human capital.

DTW results confirm human capital in the Polish regions is not fully utilized, which allowed us to achieve our research goal. Regional disparities are increasing especially within innovativeness which means knowledge, creativity, and experience of society are not translated into innovation. The problem here is financial and material capital. As a result of the polarized development model used in the Polish regional development policy, where mainly large urban units and metropolises are supported, there is a lack of financing sources for high-risk projects in economically weaker towns and regions.

Adjustment processes showed a short-term character, which means that on average, over the entire period, the level of inequality in human capital and innovativeness did not decrease. The problem can be the heavily industrialized and still notably agrarian structure of the Polish economy, which is based on labor-intensive sectors and consists mainly of micro, small, and medium-sized companies. Moreover, company development strategies are dominated by opportunism and acting from the perspective of short-term goals. The lack of success in reducing disparities in human capital and innovation is also an aftermath of Poland's polarization and diffusion of development policy. This model has changed since 2016 after the election of a new government, which has set as a development priority the equalization of opportunities, support for smaller towns, and social, economic, and territorial cohesion. However, it is too early to assess what effect this paradigm shift has had on the development disparities of Polish voivodeships.

Current regional disparities are partially explained by geographical and historical factors. The clear division into emerging and more developed regions, mainly corresponding to former Partitions' borders. The 123 years of Poland's absence from the map of Europe (between 1775 and 1918) and functioning as part of three different economic organisms (under three occupiers) have left a mark that is still visible today (Figure 4).

This historical and geographical accumulation of human capital can be linked to the average state of human capital and innovativeness of Polish regions within the years 2004–2018 (see Figure 5).

4. Discussion

The adopted methodology allowed us to achieve our research objective because of its ability to show the development and adjustment processes of human capital and the innovativeness of Polish regions. The results of the study are consistent with the current map of regional disparities in Poland (Czyż & Hauke, 2011; Gorzelak, 2006; Gurgul & Łach, 2019; Opiłowska, 2019; Wielki et al., 2018), which proves the hypothesis that human capital is the main source

Figure 4. Borders of the partitioned states in the 18th and 19th centuries on the current map of Poland (source: Churski et al., 2021)

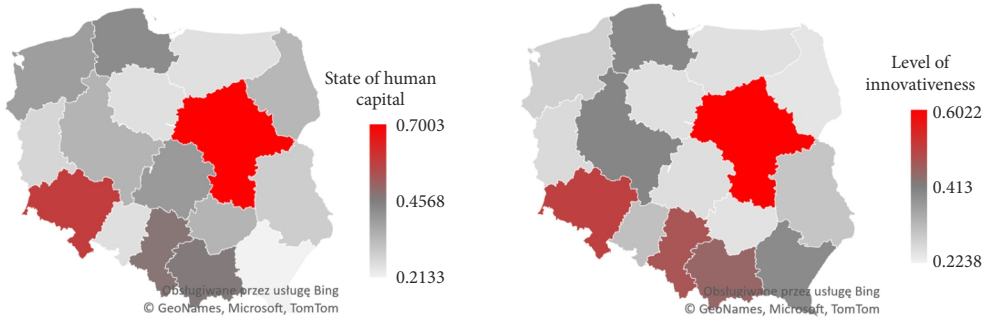

Figure 5. Average state of human capital and innovativeness in the years 2004–2018 on the current map of Poland (source: own elaboration)

of regional disparities and explains them. In addition, it follows that current disparities have been influenced by the historical and geographic accumulation of human capital. Human capital is the product of longevity. This resource level is higher in regions where in the past, functioned efficient institutions and a higher degree of democratization of socio-economic life, which is the basis of an inclusive society (Abramson et al., 2001; Becker et al., 2020; Dittmar & Meisenzahl, 2020; Gawthrop & Strauss, 1984; Johansson, 2009; Piatkowski, 2018).

Historical factors and economic geography have translated into Poland's modern development dualism, centered around its East-West axis. This state is similar to the overall European divide with more developed Western European countries and less developed Eastern European countries (former Eastern Bloc members) (Churski et al., 2021; Grosfeld & Zhuravskaya, 2015).

Differences in the development of regions, for example, those of historical or geopolitical nature, should be considered in strategic plans for national development. Human capital is a good illustration, as it accumulates over more extended periods. Regional differentiation is neither a factor taken in place in national nor regional programs. However, this may change soon, since, since 2015. Poland is moving from diffusion-polarization to a sustainable model. Will the change prove beneficial, remains to be seen. The current regional development process is dominated by market primacy and efficiency, mainly contributing to the more substantial regions and urban centers.

The historical and territorial accumulation of human capital is consistent with Myrdal's theory of cumulative causality (Myrdal, 1957). Differentiation of the development of the people factor within Polish voivodeships confirms the assumptions of polarization theories: e.g. Perroux's growth poles (1950), Hirschman's uneven development (1958), Friedman's core and periphery (1972). The first places in the rankings in terms of human capital and innovativeness of regions with large academic centers correspond to Storper's learning region theory and Scott (2009) and Florida's creative class (Florida, 1995). However, neither of these theories seems to have dealt with regional disparities and failed to consider the factor of historical and geographical accumulation of human capital. Furthermore, the DTW results obtained confirm the assumptions that human capital is not fully utilized, and regional disproportions result mainly from inadequate distribution of this factor (Erdem, 2016). Experience shows that past policies have improved the overall situation, but have also led to a further increase in regional disparities. Some remedies for this state of affairs came with the New Economic Geography, endogenous development theory, or New Structural Economics (Lin, 2012) promoted in Poland since 2015. The Polish government implemented its central national development policy for sustainable growth (*The Strategy for Responsible Development for the Period up to 2020* (*Including the Perspective up to 2030*), 2017). The Strategy emphasized the importance of internal potential and comparative advantages of regions. However, it is too early to assess the effectiveness of this policy in Poland.

Our greatest contribution to the article is a unique study of human capital and innovation development paths and adjustment processes of Polish regions based on a broad set of characteristics. The results are also valuable because they indicate that despite the country's socio-economic growth, regional disparities are not diminishing, and are even increasing. This is an essential conclusion, especially for public authorities. So, why are these disparities growing? The answer should be sought precisely in the unequal distribution of human capital. Public policies have so far pushed for development based on growth poles, and metropolises. It was thought that centrifugal forces would also contribute to the development of weaker regions. Unfortunately, this has not been the case, which suggests that development strategies need to focus on greater economic, social, environmental, and territorial cohesion. The mechanisms described in the trickle-down theory have not worked. This theory, which says that economic growth benefits everyone ("a rising tide lifts all boats"), has not worked. We should raise the question here: what policy should be adopted for developing human beings? This discussion is especially important for emerging economies like Poland. Quality of social life depends on qualitative factors such as life satisfaction or well-being and not on macroeconomic indicators such as GDP per capita.

The discussion around human geography should consider the mechanisms of human development and its territorially oriented economic activity. The geographical and historical accumulation of economic resources is a critical factor in developing regions. It essentially explains the degree of disparity between them.

A certain limit to our survey is the range of features, which in this case is broad. due to the availability of data from the Polish statistical office. It is uncertain whether the same range of data will be available for other countries. Another point is that the paper does not directly indicate which factor within human capital influences innovation to the greatest extent. Further research is needed to determine this. In addition, Polish voivodeships are not homogeneous, and often within them. there is additional differentiation. A glaring example is the Mazowieckie Voivodeship. It is a model province, while only the capital Warsaw and its neighboring towns achieve strong results, while the rest of the region ranks last in the country in various surveys. However, we use some regional averaging, which is a simplification for studying differences between regions but does not capture all the causes of disparities. After all, the fact that metropolises and cities, in general, stand out from the rest of the areas (small towns and rural areas) is a fact. In our opinion, this is, among other things, a derivative of the regional distribution of human capital.

The large number of factors taken to describe human capital and innovation can give the impression that the resulting picture is fuzzy. Nevertheless, it should be considered that the construction of the index used 5 alternative methods of weighting the characteristics, which without the risk of losing information, selected the most important ones, assigning very little importance to the others.

We proved that there is a positive link between human capital and innovativeness in regions, which is in line with previous research (Faggian & McCann, 2009; Pater & Lewandowska, 2015; Teslenko et al., 2021).

We used dynamic time warping (DTW) to explain the problems with equalizing development disparities and adaptation processes of Polish regions with model voivodeship's growth path – Mazowieckie.

Regional disparities in human capital and innovativeness raise concerns for the future, especially in the context of the 4th industrial revolution based on digitization and automation. If the disproportions continue to grow, they may cause a significant increase in digital exclusion. Today, universal skills that prepare for a rapidly changing world are essential.

Due to dynamic social needs changes, modern education should be based on achieving professional competencies and universal competencies, allowing university graduates to adapt to the very dynamic and continuously changing labor market requirements, which was shown in the literature section (Li et al., 2018). Higher education institutions should anticipate the needs of the labor market by, for example, developing skills that are durable in time. One such skill is the ability to draw hidden and more profound meanings. which becomes increasingly valuable in a digitizing world, where machines will be able to perform simple repetitive processes. The features that define the competencies of a modern university graduate, such as social intelligence, help find solutions that are not subject to strict, defined rules. Multicultural competencies and analytical thinking also gain importance. Therefore, understanding future workers' competencies must be reoriented to release as much of their human

capital as possible. Equal access to information, computers, the Internet, and education is therefore essential. It is also necessary to prepare the younger generations for new technological change challenges, megatrends, metropolization, globalization, and health crises.

In future research, the authors will examine what factor most influences the formation of inequalities and what can be done within the framework of human socio-economic activity to make development serve the entire society and have an integrated dimension.

Conclusions

Using dynamic space-time curvature, we estimated that Polish voivodeships diverged from each other both in terms of human capital and innovation. Thus, we have achieved the goal, which was to show the development paths and adjustment processes of these two development factors. Mazowieckie, home to Poland's capital, has been developing much faster, especially in innovation. However, it should be mentioned that Mazowieckie's development locomotive is Warsaw, and the region itself is highly polarized. The pace of development of human capital in Polish regions and the adjustment processes to the Mazowieckie voivodeship is faster than for innovation. It proves our second research objective, the incomplete use of human capital in creating innovativeness. Historical and territorial accumulation of human capital still plays a big role in identifying the current regional disparities,. which were in our research interest. These disparities within human capital coincide with the map of regional disparities. This confirms the accepted hypothesis that human capital is the main factor in regional disparities and explains them. The findings confirm previous theoretical and empirical directions, but also provide new light for regional research on such important factors as human capital and innovation.

Our findings could be value added for policymakers. We recommend focusing on sustainable strategies within humans in public policies addressed to regional development. We suggest analyzing development in ways that reach beyond quantitative measures, but rather are centered on productive and renewable use of resources. There is a need for a holistic approach to development processes, considering the functional areas of regions, cities, and rural areas, optimally utilizing their development potential. Achieving economic, social, environmental, and spatial cohesion requires integrated action on many levels. The polarization-diffusion model (core and periphery) of development policy led to an increase in regional disproportions in human capital and innovativeness. Supporting metropolization processes increases the potential of big cities locally, but not globally. Regional disparities increased, which led to many cities losing their socioeconomic functions, and others are threatened with marginalization.

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Authors contribution

MJ: conceptualization and data curation, original draft, review and editing; MS: conceptualization and data curation, methodology, original draft, review and editing.

Competing interests

There are no conflicts to declare.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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