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The authors investigated how economic growth affects the disparity in the distribution of regional income in Poland and vice versa. The research was based on annual data covering the period 2000–2009. In general, the research was divided into two main parts. First, the authors examined the evolution of the level of spatial inequalities in income in Poland over the last decade using the concepts of sigma and beta convergence. Next the nature of causal dependences was investigated between this inequality and economic growth. It was found that Polish regions did not converge with respect to the distribution of income as total GDP grew. The second part of the research provided evidence to claim that this inequality caused growth. Moreover, the evidence was also found that growth affected regional inequality. Finally, the authors noticed that the effects of both these factors were positive. The results suggest that as a consequence of rapid economic growth, some regions in Poland seized new opportunities, while less developed regions were unable to keep up with the challenging requirements of a decade of fast economic growth.

Keywords: *regional inequalities, economic growth, sigma and beta convergence, Granger causality*

1. Introduction

Widely observed income inequalities may be induced by entrepreneurship, innovation, work effort, as well as more risk taking (see, e.g. [27], [6]). Interregional disparities in income depend on differences in regional economic structures. These structures have a crucial impact on the value added per employee in a sector. The larger number of employees in agriculture, fishing and forestry in a region, the lower value

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added per capita in this area. Moreover, in CEE countries, traditional industries in manufacturing regions significantly shrank in size during the period of transition (e.g. the regions of Katowice and Łódź in the case of Poland). To make matters worse, the plants and factories closed were not replaced by any new form of employment. Also, the economic situation of other regions in which industry was dominated by raw material extraction worsened during the period of transition. In general, only the regions in which large cities are located exhibited a high rate of economic growth. In the case of Poland, the largest CEE country in transition, the worst economic situation (even a decrease in GDP per capita) was experienced by eastern rural provinces.

In common opinion, inequality at a personal or regional level contradicts fairness. Moreover, income polarization is one of the main sources of social tension, which tends to increase socio-political instability among social classes or across poor and rich provinces. Consequently a high level of socio-political instability can have a negative impact on economic growth. Individual investment decisions are made under uncertainty about the political and legal environment. This kind of instability can slow down market activities and cause negative effects on the labour market. Finally, labour productivity and economic growth can be reduced. This observation is a source of concern for policy makers in respect to the choice between more growth and more equality. It has been suggested that any movement towards reducing income inequality through redistributive fiscal policies may bring about a long-run reduction in growth rates because of reduced efficiency (see [10]).

In recent contributions, there has been an increasing interest in the opposite direction of causality, i.e. the possible effect of economic growth on income inequalities or disparities among provinces.

Nowadays, there is no doubt that the level of economic inequality among social groups or disparity among provinces in a country can reflect its economic performance. However, the question as to how income inequality or disparity between provinces affects economic growth is still unresolved. Some authors have found that inequality exhibits negative effects on growth, while others have noted positive effects, which is in line with neoclassical theory. The authors tried to explain such contradictions. They found that a negative relationship is typical of less developed countries, whereas a positive association characterises highly developed countries. An alternative explanation for this discordance is that growth rates first rise and then decline with the initial inequality.

The main goal of the paper was to investigate the causal relationship between disparities in regional income and economic growth by using data on Poland's economic growth and spatial income disparities over sixteen provinces for the period from 2000 to 2009. In order to do this, we applied the concepts of sigma and beta convergence, along with various methods of testing for causal effects in a panel framework.

The structure of the paper is as follows. The theoretical and empirical results concerning the relationship between income inequalities, in particular disparities at re-

gional level and economic growth are reviewed in the following section. The main hypotheses are presented in the third section. The data are described in Section 4. The methods applied are outlined in Section 5. Empirical results and a discussion are provided in Section 6. Major conclusions and some policy recommendations are given in the last part of the paper.

2. Literature overview

The theoretical literature on the relationship between regional disparities and macroeconomic performance has expanded in recent years. This is connected with rising interest in the determinants of economic growth which has been observed from the beginning of the 1990s.

Most of the previous studies concerned with regional disparities in per capita income applied the concepts of sigma and beta convergence introduced by Barro and Sala and Martin [4], [5]. These measures colligate the information provided by dispersion with the estimation of convergence equations. However, as mentioned in some papers (e.g. [23]–[26]), a number of econometric problems arise when applying this approach. It is often pointed out that this type of analysis provides only a partial view of the observed distribution. It neglects the possibility that various regions may change their relative positions over the study period. This type of analysis completely ignores the possibility of intra-distribution mobility. As stressed by Ezcurra et al. [11], the standard convergence approach also ignores the fact that a reduction in dispersion in the distribution under consideration may be compatible with a process of polarization into several internally homogeneous regional clusters. These regional clusters, known in the economic growth literature as convergence clubs (see, e.g. [11], [26]), are based on the possibility of the existence of multiple, locally stable, steady state equilibria (for details see [9]). In such a framework, various economies converge towards one another if their initial conditions are close to the pole of attraction of the same steady state equilibrium.

Besides the basic concepts of sigma and beta convergence, empirical research on regional disparities often uses the idea of causality in the Granger sense. Pérez-Moreno [21] examined the causal relationship between economic growth and income inequality in Spanish provinces from 1970 to 2000. He used a panel of data with only four observations of the variables for each province at given times. Then a modified form of the traditional Granger causality test was used to suit the short time series that was available. Applying a sum-difference test, he concluded that the empirical evidence supports the hypothesis that growth in the gross domestic product (GDP) per capita in Spanish provinces leads to less income inequality.

Ezcurra [12] investigated causal dependences between income polarization and economic growth in the regions of the European Union over the period 1993–2003. He found that the level of income polarization is negatively associated with provincial growth. According to this author, the uneven spatial impact of an intense transition period is evident and therefore this issue should be closely investigated.

Interregional disparities in Europe were investigated in recent years in connection with the new geo-political orientation of the CEE countries. From a theoretical point of view it was expected that decentralization in transitional countries from Central and Eastern Europe should lead to an uneven distribution of resources among provinces in these countries ([7], [20]). This has been interpreted as a direct consequence of the weakening of the position of central government which equalized disparities among regions under the former centralized system. The prediction was that the more developed provinces with better developed infrastructure and better qualified labour will win this competition, which in consequence should cause an increase in the distance between the most developed areas and rural areas (see [22]).

Increasing attention has been paid to models of regional disparities within countries, which are based on the assumption that trade liberalization can affect regional disparities within countries, as producers either move closer to a border to secure market access to foreign countries, or closer to the centre to benefit from a larger market. In CEE countries, regions being geographically close to Western Europe are favoured (see [3]). These regions usually attract foreign investors, predominantly from the old EU15, mainly due to cross-border collaboration (see [13]). On the other hand, the process of economic recovery in eastern areas of Poland and other CEE countries is not easy. These regions did not attract much attention among foreign investors, mainly due to their poor infrastructure and human capital stock, which they inherited from the former economic system. Agriculture remains a major field of economic activity in these regions (see e.g. [14], [8]).

Concern for regional development in Poland was already apparent during the era of centrally planned economies. This was demonstrated by various initiatives related to spatial planning within a sectoral framework, which were designed by the central government. After the collapse of centrally planned economies, the problem of regional inequalities in income became less important. The new democratic government in Poland placed emphasis on political and macro-economic reforms, in order to overcome a deep recession, which affected Poland in the early 1990s. Since the middle of the 1990s, Poland and other CEE countries were heading towards a specifically regional policy, although this process was on rather a small scale ([2]). One of the forms of the regional equalization policy in Poland was a legal obligation to regularly transfer (each year) a certain amount of money from rich to poor provinces. However, an overly large number of objectives and lack of sufficient funds led to the failure of regional policy in most rural and disadvantaged regions.

Our analysis will be performed based solely on Polish data, because Poland is the largest transitional economy and to the best of our knowledge there are no contributions concerning the dynamic link between disparities in regional income and economic growth for any individual transitional country in Central and Eastern Europe (in particular Poland). Therefore, such an analysis may be of interest to policy makers both in Poland (in terms of maintaining its economic development and holding its position of CEE leader), as well as in other economies in transition.

Despite the technical imperfections mentioned at the beginning of this section, we will use not only the notion of causality, but also the concepts of beta and sigma convergence in our study. This enables comparison of our findings with the empirical results obtained in previous papers related to regional disparities.

Taking into account the results of contributions reviewed in this section, we will formulate the main hypotheses concerning the relation between spatial inequalities in income and economic growth in Poland over the last decade.

3. Main research hypotheses

The first step of our analysis is based on an analysis of proxies for the growth of the Polish economy and for regional inequalities in income. The choice of proxies was restricted by the availability, consistency and reliability of data. As a measure of the growth of the Polish economy we used $\ln(GDP_t)$, where GDP_t denotes annual data on real GDP per capita (based on prices in 2000) in Poland in the period from 2000 to 2009. The relative wages and relative disposable income (in relation to the national averages) for all sixteen Polish regions were used as measures of regional inequality. A first look at the data led us to the conclusion that probably there has been no regional convergence in the income distribution between poor and rich regions over the last decade, especially after 2004. To formally verify this supposition, we will test the following hypothesis using the concepts of sigma and beta convergence.

Hypothesis 1. It seems that Polish regions are not converging with respect to income distribution as total GDP grows. Moreover, since EU accession, the differences in the income distribution between poor and rich regions have become even greater.

Taking into account the above hypothesis, we will check the structure and directions of Granger causal interdependencies between spatial inequalities in income and the economic growth of Poland in the period from 2000 to 2009. The dependence (causality) between a country's economic growth and relative changes in wages and salaries was reported in some contributions reviewed in the previous section. Taking this into account, we formulate the other hypothesis.

Hypothesis 2. Real growth in GDP per capita Granger caused relative changes in wages and salaries across Polish regions.

In general, visual inspection of the data suggests that disposable income was rising in all the Polish provinces as GDP grew. However, it seems that the poorer regions moved away from the country's average in the period under study, which indicates that income in poorer provinces increased more slowly than in the richer ones. It is an important research avenue to test whether this decrease in relative income across poorer provinces with no pronounced changes in the relative income of richer provinces was a consequence (in the sense of significant Granger causality) of the country's overall economic growth. Thus, we may formulate the next hypothesis.

Hypothesis 3. The overall economic growth in Poland Granger caused a drop in the relative disposable income (in relation to the national average) of poorer regions in the last decade.

In other words, the country's GDP growth increased the gap between the levels of disposable income in richer and poorer provinces. Some contributions mentioned in the previous section provided a basis to claim that a dependence (causality) running from relative changes in wages and salaries, as well as from disposable income to the economic growth of a country is also likely to exist. Therefore, we may expect this direction of causality to also appear in the case of Poland.

Hypothesis 4. There was causality in the Granger sense running from relative changes in wages and salaries, as well as from relative changes in disposable income, to the growth of the Polish economy.

Several statistical tests are applied in this paper (in- and out-of-sample methods, asymptotic and bootstrap methods). The use of all these methods was especially important with respect to the validation and robustness of empirical results. Thus, it is especially important to check the final hypothesis.

Hypothesis 5. The results of the tests for interdependencies between regional disparities in Poland and economic growth seem to be robust against the econometric procedures chosen.

In the next section we will introduce the dataset and conduct (by means of suitable descriptive statistics and plots) a detailed description of performance according to chosen indicators over time and regions.

4. The dataset and its properties

One major problem related to analysing spatial inequalities in income in Poland, especially in terms of causal interrelations with the country's economic growth, is the

Table 1. Short description of the sixteen Polish provinces (2009 data)

Province	Total area [km^2]	Total population /population/km^2 [thousands/unit]	Percentage of total population living in urban areas	Persons in agriculture, forestry and fishing (as % of total)	Region	Main forms of economic activity
Dolnośląskie	19 947	28766/144	703	75	South-western	mining, iron and steel industry, ceramics, power industry, agriculture
Kujawsko--pomorskie	17 972	20690/115	607	171	Northern	agriculture, food industry, chemical industry
Lubelskie	25 122	21572/86	465	366	Eastern	agriculture and food industry
Lubuskie	13 988	10100/72	636	89	North--western	textile industry, iron and steel industry, food industry
Łódzkie	18 219	25418/140	642	204	Central	textile industry, food industry, chemical industry, agriculture
Małopolskie	15 183	32983/217	493	163	Southern	power industry, leather industry, paper industry, food industry
Mazowieckie	35 558	52222/147	646	142	Central	food industry, electrical industry, engineering industry, petrochemical industry, agriculture
Opolskie	9412	10311/110	523	158	South--Western	engineering industry, automotive industry, chemical industry, food industry
Podkarpackie	17 845	21017/118	411	238	Eastern	food industry, agriculture, forestry, engineering industry
Podlaskie	20 187	11897/59	602	339	Eastern	wood industry, agriculture
Pomorskie	18 310	22301/122	662	83	Northern	food industry, shipbuilding industry, chemical industry, shoe industry
Śląskie	12 333	46407/376	781	43	Southern	mining, iron and steel industry, power industry, textile industry, building industry
Święto-krzyskie	11 711	12701/108	452	317	Eastern	food industry, agriculture, forestry, chemical industry
Warmińsko--mazurskie	24 174	14270/59	599	163	Northern	food industry, forestry
Wielkopolskie	29 826	34083/114	561	159	North--Western	food industry, metal industry, furniture industry, mining
Zachodnio--pomorskie	22 892	16932/74	687	89	North--Western	food industry, shipbuilding industry, forestry, power industry

lack of time series data of sufficient size. This is partly due to the reform of public administration which took place in 1999 (this stage of decentralization in Poland caused a reduction in the number of provinces from 49 to 16, the restoration of 373 counties, and the decentralisation of public programs and services to these two levels). Therefore, the analysis of causal dependences between economic growth and the income distribution is based on an alternative approach for the evaluation of panel datasets. Table 1 contains a short description of the sixteen Polish regions, which seems to be especially useful for a reader who is not familiar with the structure and profile of the Polish provinces.

The dataset used in this paper contains annual data on real GDP per capita (based on prices from 2000) in Poland in the period from 2000 to 2009, which is the indicator of the overall development of the Polish economy in the last decade. Moreover, we used annual data on average gross wages and salaries and average disposable income per capita in the period from 2000 to 2009 for all sixteen Polish provinces. The data was obtained from the Statistical Office in Cracow. The choice of such indicators allows examination of the properties of regional inequalities in income in Polish society and its dynamic connections with the economic growth observed in recent years. In order to measure relative changes in income per capita in all Polish provinces, each measure of income for each province was divided by the national average.

Since the natural logarithm belongs to the set of Box–Cox transformations, its application stabilizes variance, which is especially important for parametric tests. In this paper, abbreviations were used for all variables. Table 2 contains a summary of the variables used.

Table 2. Units, abbreviations and short description of variables

Initial variables			Transformed variables	
Description of a variable	Unit	Abbreviation	Description	Abbreviation
Real gross domestic product per capita in Poland (based on prices in 2000) in year *t*	PLN	GDP_t	Measure of the overall performance of the Polish economy in year *t*	$\ln(GDP_t)$
Average gross wages and salaries in Poland in year *t*		$WAGE_t$	Measure of distance between wages and salaries in the *i*-th province in year *t*, and the national average	$\ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right)$
Average gross wages and salaries in the *i*-th province in year *t*		$WAGE_{i,t}$		
Average disposable income per capita in Poland in year *t*		$DINC_t$	Measure of distance between disposable income in the *i*-th province in year *t*, and the national average	$\ln\left(\frac{DINC_{i,t}}{DINC_t}\right)$
Average disposable income per capita in the *i*-th province in year *t*		$DINC_{i,t}$		

It is worth mentioning that the interregional differences in wages and salaries (or disposable income) may be the result (at least partially) of interregional variation in prices. Therefore, we first used the data (provided by the Central Statistical Office of

Poland) on prices of consumer goods and services in Polish provinces in 2000 in order to capture the price differences between Polish regions. Next, we applied the regional (national) inflation rate to deflate the $WAGE_{i,t}$ and $DINC_{i,t}$ ($WAGE_t$ and $DINC_t$) time series in the years 2001–2009. In order to reduce the number of symbols used, henceforth the symbols described in Table 2 are used to denote deflated variables.

In the initial part of our analysis we examine some basic properties of our data. For the sake of transparency, we do not present descriptive statistics and plots of relative wages and relative disposable income for all sixteen Polish regions. We restrict our analysis to just the Mazowieckie province (highest wages and disposable income in 2000, denoted as *M* in Table 3) and the Podkarpackie province (lowest wages and disposable income in 2000, denoted as *P* in Table 3).

Table 3. Descriptive statistics for the variables analyzed

Statistics	Variable				
	$\ln(GDP_t)$ $[\Delta\ln(GDP_t)]$	$\ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right)$ $\left[\Delta\ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right)\right]$		$\ln\left(\frac{DINC_{i,t}}{DINC_t}\right)$ $\left[\Delta\ln\left(\frac{DINC_{i,t}}{DINC_t}\right)\right]$	
		P	*M*	*P*	*M*
Minimum	7.546 [0.005]	–0.169 [–0.008]	0.232 [–0.012]	–0.289 [–0.046]	0.179 [–0.037]
First quartile	7.584 [0.016]	–0.167 [–0.006]	0.246 [–0.009]	–0.272 [–0.026]	0.206 [–0.016]
Mean	7.650 [0.027]	–0.160 [–0.002]	0.251 [–0.003]	–0.235 [–0.009]	0.224 [0.005]
Third quartile	7.707 [0.037]	–0.158 [0.001]	0.253 [0.002]	–0.207 [0.004]	0.245 [0.019]
Maximum	7.794 [0.054]	–0.144 [0.007]	0.271 [0.005]	–0.201 [0.021]	0.262 [0.052]
Standard deviation	0.089 [0.018]	0.008 [0.005]	0.012 [0.008]	0.036 [0.021]	0.029 [0.028]

Comprehensive initial analysis also requires examination of the plots of the variables under study. Figure 1 contains the corresponding plots.

The upward tendency in the plot of $\ln(GDP_t)$ (see Fig. 1a) provides evidence of the relatively stable development of the Polish economy in the last decade. At this point it should be noted that the Polish economy was one of the few in Europe that managed to avoid the undesirable impact of the crises of 2001 and especially of 2008. However, before 2002 and after September 2008, a slight slowdown in the rate of growth of real GDP per capita can be observed.

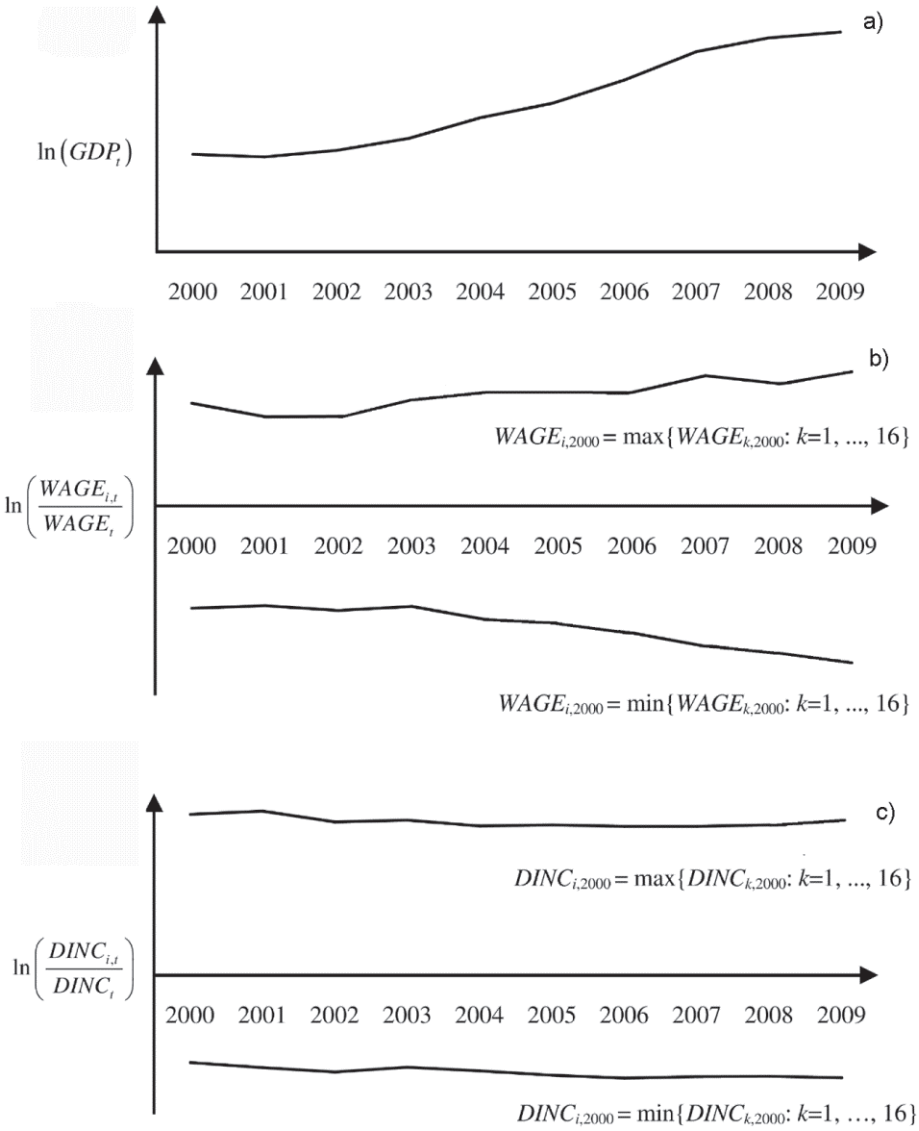

Fig. 1. Plots of the variables used in further analysis

As one can see, no matter which measure of income is applied (see Figs. 1b, c), the distance between the Mazowieckie and Podkarpackie provinces did not diminish over time (as a matter of fact, in the case of wages an increase is clearly visible). This supposition will be formally tested in Section 6 on the basis of data from all the provinces. In the next section we will present a brief description of the econometric tools applied in this paper.

5. Methodology

The empirical research performed in this paper is based on two methodological concepts. First, we aimed to examine the issue of spatial inequalities in income in Poland using the concepts of beta and sigma convergence. After checking some basic properties of the income distribution for the period from 2000 to 2009, we checked whether there are any dynamic dependences between the income distribution and the overall economic growth of Poland.

5.1. Concepts of beta and sigma convergence

The idea of convergence is based on the hypothesis that poorer provinces will tend to grow at faster rates than richer ones. In the literature, two specific concepts of this catch-up effect are especially common, i.e. beta and sigma convergence.

In general, beta convergence occurs if poor regions tend to grow faster than rich ones. In practice this issue is examined by means of the following regression model:

$$\frac{1}{t_1 - t_0} \ln\left(\frac{y_{i,t_1}}{y_{i,t_0}}\right) = \alpha + \beta \ln(y_{i,t_0}) \tag{1}$$

where y_{i,t_0} (y_{i,t_1}) denotes the initial (final) value of a welfare measure (wages, salaries, disposable income etc.) in region i. If β is negative (positive) and statistically significant, one may say that beta convergence (beta divergence) appears to be present. In other words, beta convergence means that poor regions (low welfare at initial time t_0) have experienced faster growth (in the period from t_0 to t_1) than rich regions (high welfare in the initial year t_0).

On the other hand, sigma convergence (sigma divergence) occurs if the cross-sectional variance of a welfare measure is falling (rising) over time for a group of regions (compared to the national mean). This type of convergence means that the following expression represents a series which is decreasing in time:

$$\delta_t^2 = \frac{1}{N} \sum_{i=1}^{N} \left(y_{i,t} - y_t\right)^2 \tag{2}$$

where $y_{i,t}$ stands for the welfare measure in region i at time t, y_t denotes the country's average welfare measure at time t and N stands for the number of regions. In order to filter out the effect of inflation, one may use ratios of the regional welfare measure to the country's mean:

$$\tilde{\delta}_t^2 = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{y_{i,t}}{y_t} - 1\right)^2. \tag{3}$$

A natural question arising after finding evidence of convergence (divergence) in the welfare distribution (represented by wages or disposable income) is whether the evolution of this distribution over time was dynamically linked with the overall economic growth of the country. In the next subsection, we give a brief overview of the econometric tools used in testing for causality in the case of short panel datasets.

5.2. Testing for causality

As already mentioned, in the case of Poland the lack of datasets of sufficient size precludes the application of standard time series methods in performing Granger causality tests. Thus, in this paper we use the alternative method of evaluating panel datasets presented by Granger and Huang [15]. This approach is focused on forecasting properties of models, rather than on estimation (as in case of the traditional approach). It has often been used in recent empirical papers dealing with regional studies (e.g. [28], [21]), since it is relatively simple. Moreover, it does not require complex pretesting procedures and is applicable even for short time periods or a small number of observations in each cross-section.

In order to present this idea we will analyze the case of testing for causality in the direction from economic growth to relative changes in wages (testing for causality in the opposite direction and/or based on disposable income requires an analogous procedure). Let I denote the examined group of regions (e.g. all available regions, only the poorest regions etc.) of a specific country. Next, consider the following two models:

$$\Delta \ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right) = \alpha + \sum_{j=1}^{p}\alpha_j \Delta \ln\left(\frac{WAGE_{i,t-j}}{WAGE_{t-j}}\right) + \sum_{j=1}^{p}\beta_j \Delta \ln\left(GDP_{t-j}\right) + \varepsilon_{i,t} \tag{4}$$

$$\Delta \ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right) = \alpha' + \sum_{j=1}^{p}\alpha'_j \Delta \ln\left(\frac{WAGE_{i,t-j}}{WAGE_{t-j}}\right) + \varepsilon'_{i,t} \tag{5}$$

where $i \in I$, p denotes the lag length and $t = p + 1, ..., T$. First, we should note that the application of first differences eliminates some time invariant individual characteristics (so-called fixed effects) of the provinces examined, which makes it possible to avoid many difficulties related to the evaluation of panel datasets for variables in their

levels (see [21] for details). Secondly, it is easy to see that Eqs. (4) and (5) describe competing models of relative changes in wages and salaries in the provinces included in group *I*. According to Granger and Huang [15], if model (4) forecasts relative changes in wages and salaries more accurately than model (5), one may claim that information on the past values of a country's economic growth rate is indeed important. In other words, a country's economic growth has significant explanatory power for describing fluctuations of wages in regions included in group *I* in comparison to national average wages.

Following the papers by Granger and Huang [15], Weinhold and Reis [28] and Pérez-Moreno [21], we have applied two forecast based testing procedures to test for Granger causality within the framework discussed:

Procedure I (count method)

1. Set $i_0 \in I$.

2. Estimate parameters in the models (4) and (5) using $i \in I \setminus \{i_0\}$ and $t = p + 1, ..., T$.

3. Obtain two sequences of forecasts for the i_0-th province for $t = p + 1, ..., T$, using models (4) and (5).

4. Obtain two sequences of forecast errors, i.e. $\left\{\eta_t^{i_0}\right\}_{t=p+1,...,T}$ (model (4)) and $\left\{\xi_t^{i_0}\right\}_{t=p+1,...,T}$ (model (5)).

5. After performing points 1–4 for all possible choices of $i_0 \in I$, define

$$p_1 = n\left(\left\{(i,t) \in I \times \{p+1,...,T\} : \left(\eta_t^i\right)^2 > \left(\xi_t^i\right)^2\right\}\right)$$

and

$$p_2 = n\left(\left\{(i,t) \in I \times \{p+1,...,T\} : \left(\eta_t^i\right)^2 < \left(\xi_t^i\right)^2\right\}\right)$$

where n(A) denotes the number of elements in the set A.

6. If $\dfrac{p_1}{p_1 + p_2}$ lies outside the range $\left(\dfrac{1}{2} - \dfrac{1}{\sqrt{p_1 + p_2}}, \dfrac{1}{2} + \dfrac{1}{\sqrt{p_1 + p_2}}\right)$ and the variance of $\left\{\eta_t^i\right\}_{\substack{t=p+1,...,T \\ i \in I}}$ is smaller than the variance of $\left\{\xi_t^i\right\}_{\substack{t=p+1,...,T \\ i \in I}}$, $\Delta \ln\left(GDP_t\right)$ Granger causes

$\Delta \ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right)$ for the provinces included in group *I* (effectively at the 5% significance level).

Procedure II (out-of-sample sum–difference test)

1. Conduct points 1–4 from Procedure I.
2. Define

$$\left\{SUM_t^i\right\}_{\substack{t=p+1,\ldots,T \\ i\in I}} := \left\{\eta_t^i + \xi_t^i\right\}_{\substack{t=p+1,\ldots,T \\ i\in I}} \quad \text{and} \quad \left\{DIFF_t^i\right\}_{\substack{t=p+1,\ldots,T \\ i\in I}} := \left\{\eta_t^i - \xi_t^i\right\}_{\substack{t=p+1,\ldots,T \\ i\in I}}$$

3. Using OLS, estimate the parameters of the regression model:

$$SUM_t^i = a + b\, DIFF_t^i + \varepsilon_t^i$$

4. If the results of a Student *t*-test confirm that $b \neq 0$ (at the chosen significance level) and the variance of $\left\{\eta_t^i\right\}_{\substack{t=p+1,\ldots,T \\ i\in I}}$ is smaller than the variance of $\left\{\xi_t^i\right\}_{\substack{t=p+1,\ldots,T \\ i\in I}}$, $\Delta \ln\left(GDP_t\right)$ Granger causes $\Delta \ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right)$ for the provinces included in group *I* (at the chosen significance level).

In general, both the procedures presented above are based on finding out-of-sample forecasts for models (4) and (5) and then checking whether the augmented model is indeed more accurate than the restricted one. Procedure I is not as powerful as Procedure II but it is robust to any covariance between and heteroscedasticity of the errors (for more details see [15]). For the sake of the comprehensiveness of our research, we additionally applied a standard in-sample Granger causality Procedure III.

Procedure III (in-sample test)

1. Estimate the parameters in model (4) using all the available information (i.e. $i \in I$, $t = p+1, \ldots, T$).
2. Test the null hypothesis that $\bigvee_{j=1,\ldots,p} \beta_j = 0$.

3. If the null hypothesis is rejected at the chosen significance level, then $\Delta \ln\left(GDP_t\right)$ Granger causes $\Delta \ln\left(\frac{WAGE_{i,t}}{WAGE_t}\right)$ for the provinces included in group I at the chosen significance level.

When performing the significance tests (e.g. *t*-test, *F*-test) using the appropriate asymptotic distribution theory (as in step 4 of Procedure II or step 2 of Procedure III), one should be aware of two serious problems. Firstly, if the required modelling assumptions do not hold, the application of asymptotic theory may lead to spurious results (see [19]). Secondly, regardless of the modelling assumptions, the distribution of the test statistic may be significantly different from the asymptotic distribution when dealing with extremely small samples. One of the possible ways of overcoming these difficulties is to apply the bootstrap technique. Bootstrapping is used to estimate the distribution of a test statistic by resampling the data. Since the estimated distribution depends only on the available dataset, it seems reasonable to expect that this procedure does not require as strong assumptions as parametric methods.

In order to minimize the undesirable influence of heteroscedasticity, the bootstrap test was based on resampling leveraged residuals. This approach has often been applied in recent empirical studies (see e.g. [16]). A detailed description of the resampling procedure applied in this paper may be found in [17]. In recent years academic discussion on the establishment of the number of bootstrap replications has attracted considerable attention (see e.g. [18]). In this paper the recently developed procedure of establishing the number of bootstrap replications presented by Andrews and Buchinsky [1] was applied. In all cases we aimed to choose an appropriate number of replications to ensure that the relative error of establishing the critical value (at a 5% significance level) would not exceed 5% with a probability equal to 0.95. The Gretl script including the complete implementation of Procedures I–III is available from the authors upon request.

The application of such a variety of methods is believed to ensure robustness and reliable empirical findings. Nevertheless, using differenced data, the structure of dynamic interrelations between economic growth and the income distribution may still depend, at least to some extent, on the individual characteristics of the provinces examined. Therefore, to examine this issue we also use several methods for choosing the members of group *I*.

6. Empirical results

In this section, the results of examining the basic properties of the income distribution in Poland and their dynamic interrelations with the country's economic growth

are presented. The data analyzed in this paper covers the period from 2000 to 2009 (this naturally means that differenced data was obtained for the 2001 to 2009 period). In general, the research was divided into two main parts. The first part was dedicated to a description of some time characteristics of Poland's income distribution in the last decade using the concepts of beta and sigma convergence (divergence). In the latter step, we aimed to check whether changes in the income distribution over the time period under analysis are a cause or rather a consequence of Poland's overall economic growth.

6.1. Evidence of divergence

In the first step we calculated the appropriate time series of variance using Eq. (3) to see whether there has been convergence or divergence of income per capita between Polish provinces in the last decade. Figure 2 presents the results obtained for $\frac{y_{i,t}}{y_t} = \frac{WAGE_{i,t}}{WAGE_t}$ (Fig. 2a) and $\frac{y_{i,t}}{y_t} = \frac{DINC_{i,t}}{DINC_t}$ (Fig. 2b).

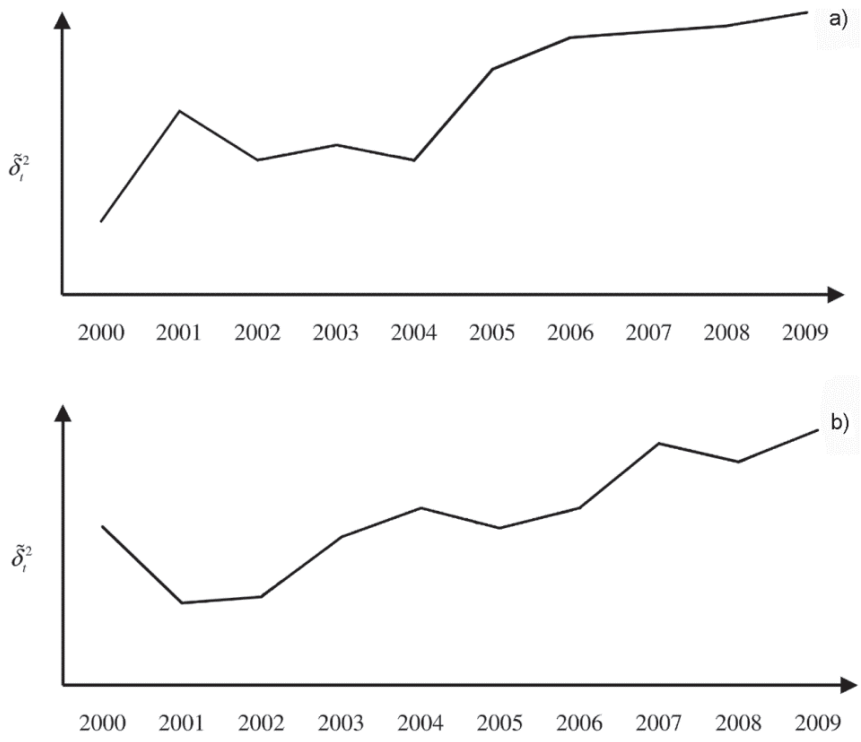

Fig. 2. Cross-sectional variation of income-related variables in Poland in the years from 2000 to 2009

In general, analysis of the graphs presented in Figure 2 provides a solid basis to claim that in the period from 2000 to 2009 one could observe sigma divergence for both welfare measures (wages and disposable income). It is also worth noting that both kinds of measures generally increased after Poland's EU accession in 2004, which is especially visible in Figure 2a (variation in wages). This seems to prove that the common opinion according to which EU accession should cause equalization in income distribution in Poland was rather false.

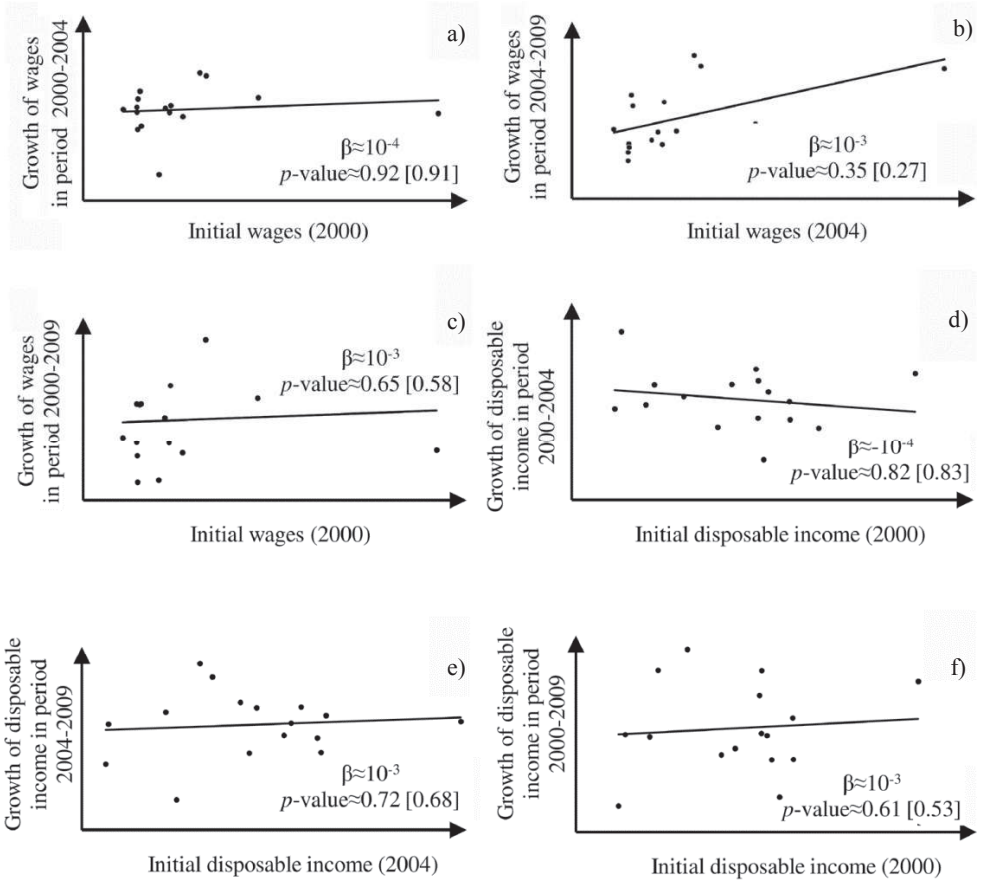

Fig. 3. Results of testing for beta convergence (divergence) for the examined income related variables in Poland in the years from 2000 to 2009

Since the lack of sigma convergence does not exclude the possibility of beta convergence, we additionally examined this issue. For both income related variables $\left(\text{in Eq. } (1) \text{ we first set } y_{i,t} = \frac{WAGE_{i,t}}{WAGE_t} \text{ and then } y_{i,t} == \frac{DINC_{i,t}}{DINC_t}\right)$ three time periods were con-

sidered, i.e. the full sample (2000–2009), the pre-accession period (2000–2004) and the post-accession period (2004–2009). The results of testing for beta divergence are displayed in Figure 3 (the numbers in square brackets denote the *p*-values obtained after the application of the bootstrap method described in Section 5).

In general, the results presented in Figure 3 provided no clear evidence to claim that over the whole research period (2000–2009) one could observe beta convergence for either income related variable (Figs. 3c, f). It is also worth noting that no evidence of significant beta convergence was found for the pre-accession period (wages, Fig. 3a; disposable income, Fig. 3d). However, in the period from 2004 to 2009 (post-accession period, Figs. 3b, e) the slopes of both lines reached greater, positive values, which is evidence of intensification of beta divergence after EU accession and supports the previous results obtained from examining sigma convergence.

As one can see, the *p*-values (both the asymptotic- and bootstrap-based variants) for the post-accession regressions also dropped in comparison to pre-accession ones. However, they were still not statistically significant. It is worth noting that after omitting the province with the highest initial values of both income related variables, the results of the appropriate linear regression indicated a significant (at the 10% level) and positive betas in the post-accession period and for the full sample, both for wages and for disposable income. This clearly confirms that after EU accession spatial inequalities in income in Poland (with respect to both measures) have indeed risen significantly.

To summarize, the plots presented in Figure 3 provide some evidence to claim that one could observe slight beta divergence in both proxies of income distribution in Polish provinces in the period from 2000 to 2009, which was more pronounced after EU accession. All these facts imply that Hypothesis 1 is clearly true. As already mentioned the interpretation of the results of testing for beta convergence requires a dose of caution, e.g. the possible presence of spatial dependence may affect the results of the growth regressions used in this context. Moreover, one must bear in mind that this part of the research was based on linear regressions performed on a relatively small number of observations, which definitely have a negative impact on the credibility of the empirical conclusions.

6.2. Causality between Polish GDP and regional inequalities in income

The finding that spatial inequalities in income have been continuously increasing in Poland over the last decade, especially in the period from 2004 to 2009, is important both for researchers and for policy makers. This conclusion is supported by results obtained from the application of two basic concepts of measuring convergence/divergence in regional income. As already mentioned, describing differences in

the level of income in Polish provinces in the last decade was only the first step of our research. This part of our paper is dedicated to testing whether the process of divergence in the levels of income in Poland in the period from 2000 to 2009 was dynamically linked to the country's economic growth, i.e. whether it was a cause or rather a consequence of the rise in GDP per capita in Poland.

Before performing an analysis of Granger causality, we decided to establish several variants for I – the set of provinces to be analyzed. Broadly speaking, we have chosen a group of the four richest and the four poorest regions using the data on wages and disposable income from the year 2000. In general, the composition of the four richest (poorest) Polish regions with respect to wages and disposable income did not change over the time period under analysis.

Performing an analysis of Granger causality for different groups of regions is important for two main reasons. First, it allows examination of the existence of different causal patterns between the overall economic growth of the country and the relative change in income in specific groups of regions. In general, this may be reflected in the directions of the causal links (for some groups spatial inequalities in income may be a cause of overall output, while for other regions causality may run in the opposite direction). Moreover, the strength of the evidence supporting the existence of a causal link may also be compared (the direction of causality may be the same for different groups, but in some cases the causal link may be much stronger). Second, an examination of groups of similar regions (poorest, richest etc.) may reduce the impact of heterogeneity and improve the statistical properties of the testing procedures described in Section 5. Table 4 contains a detailed description of the three main groups of Polish regions examined in this paper.

Table 4. Description of the groups of provinces examined in this paper

Group of provinces	Member provinces
I_0	all provinces
I_1	richest provinces (Mazowieckie, Śląskie, Dolnośląskie, Pomorskie)
I_2	poorest provinces (Świętokrzyskie, Lubelskie, Podkarpackie, Warmińsko-Mazurskie)

Table 5 contains the results of testing for Granger causality from the overall growth of the Polish economy (represented by real GDP per capita) to relative changes in wages. All testing procedures were performed at the 5% significance level. For the tests based on asymptotic and bootstrap critical values there was no case in which exactly one p-value (obtained for either the asymptotic- or bootstrap-based test) was greater than 0.05. This is why the presentation of separate results for asymptotic- and bootstrap-based significance tests is not needed for Procedure II and Procedure III.

This remark is also valid for the results presented in Tables 3–6. One should also underline that complete, detailed results of all the preliminary tests applied in our research which are not presented in the text (to save space) are available upon request.

For the sake of comprehensiveness, three values of the lag parameter were applied for each of the pairs of models (augmented and restricted). Moreover, we performed the analysis of Granger causality not only for the three groups described in Table 4, but also for three additional sets (all but the richest, all but the poorest, all but the richest and poorest), which made our analysis even more thorough. For the sake of transparency of the presentation of our results, shading was additionally used to mark finding causality at the 5% significance level. Despite using first differences we examined the stationarity properties of the data, since it is a well known fact that an OLS-based approach is likely to produce spurious results for short (in both time and cross-sectional dimensions) nonstationary panels and time series.

Table 5. Results of testing for Granger causality from overall economic growth in Poland to relative changes in wages and salaries

Group of provinces	Testing procedure			
	I	II	III	Lag length (p)
I_0	causality	no causality	causality	1
		causality		2
	no causality			3
I_1	causality	no causality	no causality	1
				2
	no causality	causality	causality	3
I_2	causality	no causality		1
		causality		2
				3
I_0/I_1		no causality		1
		causality		2
				3
I_0/I_2		no causality	no causality	1
		causality	causality	2
				3
$I_0 \setminus (I_1 \cup I_2)$		no causality	no causality	1
		causality	causality	2
				3

Thus, before performing pooled OLS based tests of significance (Procedure III), we applied a number of unit root tests allowing for common (Levin, Lin and Chu test, Breitung test) or individual (Im, Pesaran and Shin test) unit root processes. Similarly, we used the ADF, KPSS and PP tests before performing each sum–difference test (Procedure II). We applied the Schwarz criterion for choosing the lag lengths, and the

Newey–West method and the Bartlett kernel for the bandwidth selection. In all the cases examined (different measures of income, different groups of provinces, time series tests (Procedure II) and pooled-OLS-based tests (Procedure III)) we found no evidence of nonstationarity at the 5% level.

The results presented in Table 5 provide solid evidence to claim that overall economic growth in Poland had a significant causal impact on the relative changes in wages and salaries (in respect to the national average) in all the groups examined, especially in I_2 (the poorest regions) and I_0/I_1 (all but the richest). This provided some evidence in favour of Hypothesis 2. Moreover, this conclusion was generally supported by the results of two out-of-sample procedures, as well as the outcomes of an in-sample test. To summarize, these two facts provide strong evidence supporting Granger causality running from GDP growth in Poland to regional inequalities in income. The previous results of this paper seem to confirm that the sign of this relationship is positive. This conclusion is a result of combining two facts: a stable rise in real GDP in Poland in the period from 2000 to 2009 and a rise in spatial inequalities of income (see Figs. 1–3).

In the next step, we tested for Granger causality from overall economic growth in Poland to relative changes in disposable income. The results are presented in Table 6.

Table 6. Results of testing for Granger causality from overall economic growth in Poland to relative changes in disposable income

Group of provinces	Testing procedure			
	I	II	III	Lag length (p)
I_0	no causality	no causality	no causality	1
				2
				3
I_1				1
				2
				3
I_2	causality		causality	1
				2
				3
$I_0 \setminus I_1$	no causality		no causality	1
				2
				3
$I_0 \setminus I_2$				1
				2
				3
$I_0 \setminus (I_1 \cup I_2)$				1
				2
				3

This time, the evidence of causality was markedly weaker. Granger causality was detected only for group I_2, which means that the growth of the Polish economy has significantly increased the gap between the disposable income in the poorest regions and the country's average. In other words, we found some support for Hypothesis 3. In general, the results presented in Table 6 confirmed the conclusion formulated after the analysis of the previous table that the poorest regions did not benefit as much from economic growth in Poland as other regions.

An interesting question is whether there are any reverse dynamic interrelations between economic growth and the income distribution. The first part of the answer of this question is presented in Table 7.

Table 7. Results of testing for Granger causality from relative changes in average wages and salaries to overall economic growth in Poland

Group of provinces	Testing procedure			Lag length (p)
	I	II	III	
I_0	causality	causality	causality	1
				2
	no causality			3
I_1	causality			1
				2
	no causality			3
I_2	causality			1
				2
	no causality			3
$I_0 \setminus I_1$	causality			1
				2
	no causality			3
$I_0 \setminus I_2$	causality			1
				2
	no causality			3
$I_0 \setminus (I_1 \cup I_2)$	causality	no causality		1
		causality		2
	no causality			3

As one can see, the outcomes presented in Table 7 provide evidence to claim that spatial inequalities in wages were a causal factor of economic growth in Poland. This result was generally confirmed by all the testing procedures. Moreover, it was found to be robust to the choice of the group of regions. In general, the results presented in Table 5 and Table 7 allow us to claim that in the last decade there was feedback between the level of regional inequalities in income and economic growth, which means that rich regions (non-rural areas, big cities, high economic activity, industry etc.) had

a significant input on overall economic growth and as a consequence have gained significant profits (in comparison to poor regions).

In the final step of our analysis, we performed an examination of the causal links in the direction from relative changes in disposable income to overall growth in GDP per capita. Table 8 presents the results of these tests.

Table 8. Results of testing for Granger causality from relative changes in disposable income to overall economic growth in Poland

Group of provinces	Testing procedure			
	I	II	III	Lag length (p)
I_0	causality	causality	no causality	1
				2
				3
I_1		no causality		1
				2
				3
I_2		causality		1
			causality	2
				3
$I_0 \setminus I_1$			no causality	1
				2
				3
$I_0 \setminus I_2$				1
				2
				3
$I_0 \setminus (I_1 \cup I_2)$			causality	1
				2
	no causality		no causality	3

In general, the results presented in Table 8 provide solid evidence to claim that spatial inequalities in disposable income Granger caused growth in GDP per capita. This conclusion is in line with the results obtained for relative changes in wages (Table 7) which clearly supports Hypothesis 4. If one takes into account the growth in real GDP per capita in Poland over the last decade (Fig. 1), as well as increasing regional disparities in income (Figs. 2, 3), it seems that the impact of income inequality on economic growth was positive.

Finally, to check the robustness of our results, which may be uncertain for small datasets, we re-ran the analysis assuming that there was no constant in either of the competing models (see Eqs. (4) and (5)). This assumption excludes the possibility of the presence of group-dependent time trends in the data.

The differences in the results were not significant and led to analogous conclusions to those obtained via an analysis of Tables 5–8, which surely is a proof of the robustness of our empirical findings. To summarize, quite strong evidence supporting Hypothesis 5 was also found.

7. Concluding remarks

The governments of most countries in transition concentrate on measures which support economic growth. They pay less attention to regional disparities which accompany the process of economic growth. However, in common opinion, especially in post-communist countries, inequality contradicts fairness. Moreover, income inequalities (which are strongly related to the division into administrative regions in the case of Poland) belong to the main sources of social tension, which in turn tends to increase socio-political instability.

The nexus between regional disparity and economic growth has recently become one of the most important streams of modern economic research. On the one hand, the processes of globalization lead to an increase in regional disparity, but on the other hand, globalization supports convergence processes and the equalization of regional economic development. In general, a key problem faced by the European Union is the equalization of economic development within the framework of cohesion policy.

In the literature, there is no unique point of view concerning the relation between economic growth and income inequalities, neither on the personal nor regional level. In the recent economic literature, income inequalities between regions are thought to be an obstacle to economic growth, especially in the case of more developed economies. Therefore, many authors advise undertaking measures to stop any rise in inequalities. However, this issue has not been examined sufficiently in the case of the transition economies of CEE.

This paper has presented the results of an empirical analysis of regional disparities, convergence and their relation with economic growth in Poland. The motivation of our research was twofold. Firstly, we aimed to examine the basic properties of the regional distribution of income in Poland over the last decade. Secondly, we tried to discover whether these properties were dynamically linked to the country's overall economic growth. Our analysis was based on annual data covering the period from 2000 to 2009. The real growth of GDP per capita was chosen as a proxy for the country's economic growth, while average wages and salaries and disposable income were used to measure differences between incomes per capita in the Polish regions. Moreover, we used several econometric techniques, including out-of-sample Granger causality tests and a bootstrap procedure, to investigate the properties of the disparities in

income distribution in Poland and its dynamic connections with economic growth in the most comprehensive way.

The results of the first part of our analysis provided evidence to claim that one can observe regional divergence in the income distribution in Polish regions over the past decade. This conclusion was confirmed by conducting an analysis based on two traditional concepts of measuring differences in regional development, i.e. sigma and beta divergence. It is also worth noting that we found quite strong evidence supporting the assertion that regional inequalities in the income distribution rose faster after EU accession than in the period from 2000 to 2004.

After finding evidence in favour of the hypothesis of divergence in regional income, we focused on examining the structure of causal dependences between regional disparities in income and the economic growth of Poland in the period under study. We found support for the claim that the overall real growth in GDP per capita Granger caused relative changes (in comparison to the national average) in wages and salaries in all the groups of regions considered. On the other hand, causality running from economic growth to relative changes in disposable income was found only for the poorest regions. In general, these results were found to be robust to the testing procedure (in- or out-of-sample methods, using asymptotic and bootstrap critical values), which is important in terms of the validation and robustness of empirical results.

We also found quite strong evidence of Granger causality running from changes in relative wages and salaries between regions, as well as from relative changes in disposable income to the growth of the Polish economy. In this case, the empirical results were found to be robust to both the type of the econometric procedure applied and the group of regions analyzed.

In most countries, at first regional inequalities increase as economic development proceeds but then tend to decline once a certain level of national economic development has been reached. However, the results of this paper confirmed an increase in income disparity between Polish provinces which means that Poland has not achieved the *turning point* with respect to regional inequalities yet. We found strong support to assert that this process was bidirectionally (in the sense of Granger causality) related with growth of GDP in Poland. Moreover, the results from the analysis of causality and an inspection of macroeconomic data seem to prove the hypothesis that the effects of both links were positive. These results support the hypothesis that the main sources of Poland's economic growth were located in industrialized regions, where most of the country's economic activity takes place (metropolises, business centres etc.). Rural regions did not participate in the development of the country's economy to the same degree as richer regions. A high rate of social exclusion, which is manifested e.g. in a high rate of unemployment, is typical of underdeveloped rural regions. In consequence, both GDP and income in these regions are significantly lower than in urban regions with large cities.

The importance of research on the regions of Poland and other transitional countries in Central Europe also follows from this paper. Therefore, a more detailed examination of the disaggregated patterns and determinants of regional inequality would be a promising research avenue to explore in the future. This, however, is strongly dependent on the availability of quality data on the Polish regions.

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