



# The contribution of the geothermal resources to local employment: Case study from Poland

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## ABSTRACT

Next to heat and energy production, geothermal energy presents with opportunities for rural and suburban areas linking sustainable development goals with expansion of new local economy sectors. We conduct the shift share analysis for the ten municipality cases of the geothermal exploitation in Poland, comparing their employment structure with their reference poviats as a control group, in the years 2005 and 2018. The results reveal a strong shift in the trade and service sectors employment in all of examined geothermal localities, outperforming the reference poviats. In the tested period, more jobs were generated in the geothermal municipalities than in poviats too. Moreover, the structure of the differential shift component indicates that the trade and services employment growth is related with the development of the geothermal spas and recreational centers in the examined municipalities. The hypothesis that the geothermal resources utilization increases the employment in the local services sectors is corroborated.

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## 1. Introduction

Among the renewable energy resources geothermal is specific to local production and consumption. The development of the renewable energies underlines the environmental benefits in the first place. Secondly, it points to the use of autochthonous resources leading to job gains and net positive impacts on the regional economies (Allan et al., 2017; Dvořák et al., 2017; Henriques et al., 2016; Martinot, 2005; Moreno and Lopez, 2008; Ulrich et al., 2012). The employment in the geothermal related sectors is comparably low in comparison to the traditional energy sectors. However, the share is expected to rapidly grow year by year aligned with the implemented renewable energy policies (e.g. Renewable Energy Directive (EU), 2018/2001). Still, the geothermal business generated circa 100 thousand jobs worldwide until 2018 (Renner et al., 2018). Moreover, the geothermal energy is said to deliver direct, indirect and induced employment to the location of exploitation (Lesser, 1994). Whereas the direct and indirect jobs indicate the dynamics of the resource utilization, the induced employment explains the effect of the renewable resource on the economy (Wei et al., 2010). The Geothermal Energy Association establishes the economic multiplier effect to

be 2.5 for a geothermal investment, meaning that each 1 USD invested in this resource results in the 2.5 USD output grow for a local economy (Hance, 2005). Shortall et al. (2015) argue that the creation of employment and of induced economic activities represent strong features of the geothermal sustainable resource compared to other renewables. Moreover, the nature of the resource and economic application possibilities encourages into further than local energy provision. Fridleifsson (1998), Konak and Pamukcu (2006), Lund et al. (2011) and Dickson and Fanelli (2013) deliver analysis of the direct geothermal use in local economies. Furthermore, the sustainable character of the renewable and its attributes for local communities development are discussed in e.g. Kunkel et al. (2012), Tomaszewska and Szczepański (2014), Barbier (2002), Canan (1986) Fridleifsson (2001) or Lund and Boyd (2016).

The innovation in the geothermal energy development are expected to as well create a societal value. Manzella et al. (2018) present the cases of Italian geothermal plants expansion that induces social benefits like direct and indirect employment. Furthermore, the these arguments stand behind the public opinion about the geothermal projects development (Pellizzzone et al., 2017; Yasukawa, 2019). The ongoing decarbonization of energy resources is proven to generate more jobs than fossil fuels according to the work of Garrett-Peltier (2017) or Muniyoor (2020). Studies of Markandya et al. (2016) observe a spillover effect

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related to the deployment of renewable energy technologies, including geothermal. This effect considers the direct and indirect employment impacts. Poland for instance, is listed among the gainers of the energy transition and employment related to the transition into renewables resources use.

With reference to the location theory principles market activities accumulate when the cost of exploiting the resources is minimum (Puu, 2003). Developed in the early twenty century by Alfred Weber, the location theory as a part of regional sciences addresses the questions about the factors and processes that induce economic activities. It aims to describe the patterns of tapping into accessible raw materials and commodities to develop a private sector (Murray, 2017). Modern interpretation of the location theory study across the topics of business sector siting, service competition, and, more generally, consumer behavior. Energy resources considered as a commodity are discussed as an location factor for commercial activities. Altman (1986) underlines the importance of energy resources in economic development. Introducing private initiatives in the renewable energies market is a condition to attract capital according to Brown (2000). Access to sustainable resources is in the study of Chou et al. (2008) a significant the factors of tourism business location. Access to the renewables resources as a location factor in industry concentrations is reported in work of Aguilar et al. (2012), Register et al. (2012) and Mehmet and Yorucu (2020). According to the assumptions of the location theory the features of the geothermal resources can impact the economic structure of a location. This paper focuses on the side of economic advantage attracting employment, not the development of the geothermal industrial site.

In the renewable energy sector, the direct employment is estimated in relation to the units of produced energy (IRENA, 2013; ESMAP, 2019). The reports discuss recent trends in renewable energy costs and investment that imply varying impacts on job creation in the different segments of the value chain. Moreover, the gaps in geothermal employment data is underlined. This article proposes a new method of measuring the indirect and induced employment, in this case in a particular economic sector. The accessibility of the geothermal resources locally introduces opportunities to use it. Geothermal water application in the recreational and health facilities are particularly found to contribute to the increase of local budgets, augmented employment and new local market specialization e.g. in tourism (Dej et al., 2013; NREL, 2004). Therefore, we aim to find out whether the local employment structure changes while using the geothermal resources. We follow the local economic structure approach of Almeida (2007) to determine changes in employment. Our study samples a selection of the geothermal municipalities in Poland and attempts to identify a shift towards the services sector by the use of the geothermal resources. The application of the shift-share analysis is a rather novel approach in the geothermal economics studies and its versatility allows to conduct employment analysis for any geothermal resources exploiting localities in the world. After introducing the research problem, the section describing the method and data follows. Thereafter, the results of the analysis are presented and research assumptions are interpreted. The conclusions and discussion section closes this paper.

## 2. Research framework and data collection

In case of Poland, the geothermal resource is available under 80% of the country's earth crust, one of the highest capacities in Europe and 40% of this potential is technically ready to deliver economically attractive geothermal heat and energy, argue Kepinska (2003) and Górecki et al. (2012). According to Skjærseth (2014) and Szulecki et al. (2016) increased geothermal production

creates a degree of energy independence from the conventional resources and imports. Huculak et al. (2015) discuss that in case of Poland, the optimal conditions for the geothermal exploitation are found in locations that are at the source of the renewable geothermal energy or in close vicinity, in relatively small-mid size municipalities with a dense housing and infrastructure network. It provides them the geothermal related opportunities such as a local energy source, jobs creation, local budgets growth and increased entrepreneurship. Yet, despite the resource potential in Poland, the geothermal renewable is mostly used for the local district heating and recreational or bathing centers purposes (Hałaj, 2015; Sowizdzal, 2018). Studies of Stanik et al. (2011), Hałaj (2012), Kowalski (2015), Kruczek (2016), Sala (2018) indicate that the geothermal establishments change the economic landscape of the municipalities in Poland, introducing new market sectors like tourism, health services and events activities, not present there before. We base our research concept on the large potential of its direct and local exploitation according to the Lindal diagram (Gudmundsson, 1988). The work of Kurek (2016) shows the relation between the resource utilization and the indicators of local economy and tourism. Kurek et al. (2020b) discuss the positive role of the geothermal recreational centers and spas in the local development. We extend the research and we formulate the hypothesis that the geothermal resources utilization leads to an increase of employment in the service sector at the municipality level. The hypothesis is derived from the assumption of service related jobs that are induced next to the development of the geothermal recreational and spa centers. It is to be tested by using the comparative employment analysis between the municipalities that utilize geothermal resources and the larger administrative areas of poviats as a control group. The concept of territorial reference is motivated in justifying the hypothesis. Therefore, we assume a different pattern in the employment structure of the geothermal municipalities economies in comparison to poviats, in the years 2005 and 2018. The control group is introduced to avoid a biased interpretation of changes in employment in the geothermal municipalities. In testing the hypothesis, we compare the geothermal municipalities with the poviat they are located in, and, secondly, these poviats with the voivodeships they belong to<sup>1</sup>. In this way, we attempt to determine if an employment structure in the geothermal municipalities differs from the region. In addition, a group of experts is approached to decide on the categories of service employment that are related to the geothermal activities on a municipal level. Using the experts knowledge next to the desk research, we can identify specified services induced by the geothermal activities.

The following Fig. 1 displays the geothermal resources activities in Poland. Although there are 54 economically viable geothermal boreholes, the actual geothermal exploitation is much lower than the country's potential (Felter et al., 2015). The resource is exploited in the municipalities that have decided to invest in the geothermal installations, therefore in fact, in less than a quarter of the geothermal capacity.

Table 1 presents ten geothermal municipalities to be examined. They use the available geothermal resources in various forms and in a different time frame. They are the main municipalities in Poland, where geothermal installations are present, except few, sole installations for the recreational purposes in

<sup>1</sup> The latest administrative reform of Poland in 1999 established the basic hierarchy of administrative division in Poland. Municipality (pol. *gmina*) is a principle territorial unit in Poland of three types: urban, urban-rural and rural. It corresponds with a concept of commune. Poviats (pol. *powiat*) are the second level unit of territorial administration, composed out of a non-fixed number of municipalities. Poviat refers to a county or district. Voivodeship, similar to a province or region, (pol. *województwo*) is the highest level of administrative division in Poland, further divided into powiats (Central Statistical Office, 2019).



Fig. 1. Geothermal resources exploitation map in Poland.

Source: Sowizdzal (2018).

other locations as e.g. Grudziądz, Poznań or Łądek Zdrój (Sowizdzal, 2018). Geothermal enterprises of various ownership, including local authorities, produce the geothermal heat and water, that are further distributed to the communal network or power the geothermal recreational centers. Geotermia Podhalańska S.A. powers four municipalities because of to their geographic proximity. Geothermal recreational centers are established in seven out of ten examined municipalities. In case of Poddebice, the geothermal recreational center was built before the geothermal municipal heating plant. Szaflary and Bukowina Tatrzańska established two geothermal recreational centers. In Bukowina Tatrzańska geothermal resources supply the recreational and health centers without further network distribution. Opposite to Stargard and Pyrzyce, where the resource is used mainly for heating and communal purposes without applications in commercial or recreational activities.

The hypothesis is to be tested using the comparative analysis of employment structure of the geothermal municipalities and poviats for the years 2005 and 2018. Because of the methodological changes introduced in the employment statistics collection in Poland, the official data, the NACE classification, is coherent from 2005 onwards. The NACE classification corresponds with the *Statistical Classification of Economic Activities in the European Community* (Eurostat, 2016) and it is the set of types of socio-economic activities, systemized in sections A–U that are carried out by economic entities. In Poland, the NACE refers to the Polish Classification of Activities (*Polska Klasyfikacja Działalności*). The NACE classification illustrates the specialization and the dynamics of economy, and as detailed into major sections is as follows<sup>2</sup>:

- A. Agriculture, hunting, forestry and fishing
- B. Mining and quarrying
- C. Manufacturing
- D. Electricity, gas and hot water supply
- E. Water supply and waste management
- F. Construction
- G. Wholesale and retail trade, repair of motor vehicles, motorcycles, personal and households goods
- H. Transportation and storage
- I. Accommodation and food services
- J. Information and communication
- K. Financial and insurance activities
- L. Real estate activities
- M. Professional, scientific and technical activities
- N. Administrative and support service activities
- O. Public administration and defense
- P. Education
- Q. Health and social work
- R. Arts, entertainment and recreational activities
- S. Other community, social and personal service activities
- T. Goods and services producing households
- U. Extraterritorial organizations

As a comparative employment analysis the shift-share method is to be used. We adopt the approach to the geothermal municipalities, poviats and voivodeships, comparing their employment figures. If the structure of employment differs between the examined municipalities and poviats, the assumed local change can be attributed to the geothermal resources exploitation. The data for the comparative analysis stems from the Local Data Bank (Local

<sup>2</sup> Polish Classification of Activities PKD, Dz. U. 251/1885, appendix to the Regulation of the Council of Ministers (Regulation of the Council of Ministers) of 24.12.2007.



**Table 1**

Geothermal activities in the selected municipalities in Poland.

Source: Polish Geological Institute ([Polish Geological Institute, 2020](https://geology.gov.pl/en/geological-institute))

	Municipality	Geothermal enterprise	Installation year	Recreational center
1	Mszczonów	Geotermia Mazowiecka SA	2000	Termy Mszczonow (2008)
2	Uniejów	Geotermia Uniejów LLC	2001	Termy Uniejow (2008)
3	Poddębice	Geotermia Poddębice LLC	2013	Termy Poddkebice (2011)
4	Szaflary	Geotermia Podhalańska S.A.	1993	Termy Szaflary (2007) and Gorkacy Potok (2015)
5	Zakopane	Geotermia Podhalańska S.A.	2001	Aqua Park (2006)
6	Poronin	Geotermia Podhalańska S.A.	2001	n.a.
7	Białystok	Geotermia Podhalańska S.A.	1996	n.a.
8	Bukowina Tatrzańska	Bukowina Geothermal Society LLC	2008	Termy Bania (2008) and Termy Bukovina (2011)
9	Stargard	G-TERM Energy LLC	2005	n.a.
10	Pyrzyce	Geotermia Pyrzyce LLC	1999	n.a.

[Data Bank, 2020](#)) at the level of NUTS 2, 4 and 5<sup>3</sup> in the years 2005 and 2018. The employment data according to the NACE sections available in the database is merged in five groups, as presented in [Table 2](#). Because of the statistical confidentiality of the data on the NUTS-5 level some of the single employment values were estimated. The full dataset that concerns employment numbers for the municipalities, poviats and voivodeships is stored in the Mendeley Data repository ([Kurek et al., 2020a](#)).

### 3. Research method

In most of the shift-share analysis, the regional economy is compared to the national economy. It decomposes employment changes within an economy over a specified period of time. In case of our study, we compare the municipality to the poviats in which it is located and consequently the poviats to the voivodeships in which it is located. Depending on the area in Poland, poviats usually compose from few to several municipalities, whereas a multiple number of poviats belong to voivodeships. This spatial approach allows to assess the change in the NACE sections employment between the examined units. [Table 3](#) depicts the pairs of areas that undergo the shift-share analysis i.e. the geothermal municipalities with poviats, and as control groups— the poviats with voivodeships. Some of the geothermal municipalities are located within the same poviats, and by reference in one voivodeship. This is explained by the geological conditions of the geothermal resources reservoirs and accessing them (see [Fig. 1](#)). The classification of the municipalities according to the type of a territorial division follows from the Polish National Official Register of the Territorial Division of the Country (TERYT).

The shift-share analysis is a quantitative method used to analyze an employment structure. It allows for descriptive examination of structural changes that are assumed to occur within a country, region or locality ([Dunn, 1960](#)). It helps to answer the question about the growth or decline of employment in economic sectors. The main objective of the share-shift technique is the quantification of geographical changes by decomposing growth rates in structural and competitive components. The shift-share analysis developed in the 1960s has matured into numerous extensions ([Keil, 1992](#); [Knudsen, 2000](#)). In case of a local approach, this method helps as well to determine if a component contributes to the local economy or impacts local competitiveness. It is done by a retrospective decomposition of variations in the selected local economic indicators. Furthermore, throughout the descriptive analysis the structural change is compared within a referenced another geographic (or administrative) area. In this

way, we can observe regional differences or assign a structural change to a particular economic sector. The shift-share analysis is therefore popularized for explaining regional factors of growth as change in employment structure ([Adao et al., 2019](#); [Herzog and Olsen, 1977](#)); determining factors of location ([Bartholomew and Peck, 1989](#)); economic forecasting ([Kurre and Weller, 1989](#)); or regional specialization ([Esteban, 2000](#); [Márquez et al., 2009](#)). [Stevens and Moore \(1980\)](#) underline the importance of solid and comparable data as a core of the shift-share analysis interpretation. Various studies that used the shift-share method discuss the impact of the renewable resources on the regional economy ([López and Moreno, 2010](#); [Otsuka, 2016](#); [Wu, 2008](#)). We apply the shift-share analysis to the employment analysis related with the utilization of the geothermal resources at municipalities level, a novel approach in the geothermal research. A municipality as the subject of the shift-share analysis is rather uncommon in the literature dedicated to this methodology, except the work of e.g. [Amorim and da Mata \(2009\)](#) and [Nogueira and Lopes \(2008\)](#), that discuss the general trends of employment at a municipal level.

We adopt the conventional [Esteban's \(2000\)](#) three factor decomposition into a structural, differential and allocative component. Since our study regards the geothermal resources exploitation in municipalities the national effect is omitted. Therefore, following [Márquez et al. \(2009\)](#) we label the components as actual shift (allocative component), differential shift (differential component) and proportional shift (structural component). [Traistaru and Wolff \(2002\)](#) provide detailed explanation of the shift-share components framework. The actual shift measures a covariance of the differential and proportional shifts, and it indicates whereas a structural change of the examined components takes place. It explains how much economic growth in a location can be attributed to overall growth rates in the regional economy. The differential shift corresponds with any local specific factors or circumstances that enabled a change in the local employment structure. [Artige and Van Neuss \(2014\)](#) link the differential shift to the concept of regional or local competitiveness. In our approach the geothermal resources exploitation in the municipalities is responsible for the differential shift in the examined economic indicator. The proportional shift explains the size of a structural economic change between the compared units. It derives from the local specialization and usually points to growth share of the competitive sectors of a local economy. The following formulas of the shift-share analysis provide the actual (1), differential (2) and proportional (3) shift scores.

$$\text{Actual shift: } S_a = \sum_{i=1}^n W_{ijt} - \frac{W_t}{W_0} \sum_{i=0}^n W_{ijo} \quad (1)$$

$$\text{Differential shift: } S_d = \sum_{i=1}^n (W_{ijt} - \frac{W_{it}}{W_{i0}} W_{ijo}) \quad (2)$$

<sup>3</sup> NUTS is the Eurostat's Nomenclature of Territorial Units for Statistics. In Poland, NUTS levels 2, 4 and 5 correspond with voivodeship, poviats and municipalities administrative units respectively (<https://stat.gov.pl/en/regional-statistics/classification-of-territorial-units/classification-of-territorial-units-for-statistics-nuts/the-history-of-the-nuts-classification/>).

**Table 2**

Groups of the NACE sections of economy.  
Source: Local Data Bank.

Group	NACE section	Field of economy
1	A	agriculture
2	B,C,D,E,F	industry, construction, energy provision
3	G,H,I,J	trade, transport, accommodation and gastronomy, information and communication
4	K,L	financial and insurance activities, real estate
5	M,N,O,P,Q,R,S,T,U	other activities including single economic activities

**Table 3**

Geothermal municipalities, poviats and voivodeships used in the shift-share comparative analysis.  
Source: Local Data Bank.

	Municipality (NUTS-5)	Type	poviat (NUTS 4)	voivodeship (NUTS 2)
1	Mszczonów	urban–rural	Żyrardowski	Mazowieckie
2	Uniejów	urban–rural	Poddębicki	Łódzkie
3	Poddębice	urban–rural		
4	Stargard	urban	Stargardzki	Zachodniopomorskie
5	Pyrzyce	urban–rural	Pyrzycki	
6	Szaflary	rural	Nowotarski	Małopolskie
7	Zakopane	urban		
8	Bukowina Tatrzańska	rural	Tatrzański	
9	Poronin	rural		
10	Biały Dunajec	rural		

$$\text{Proportional shift: } S_p = S_a - S_d, \quad (3)$$

where

$W_{ij0}$  : the variable  $i$  in municipality  $j$  or poviat  $j$  or voivodeship  $j$  in year 0 (starting year)

$W_{ijt}$  : the variable  $i$  in municipality  $j$  or poviat  $j$  or voivodeship  $j$  in year  $t$  (final year)

$$W_t : \sum W_{it}$$

$$W_0 : \sum W_{i0}$$

Heijman and Schipper (2010) and Shi and Yang (2008) find the relevance of introducing the relative shifts for a better comparison of the examined regions or areas. They are obtained by dividing each shift (actual, differential and proportional) score by the  $t$  value in year 0; in our case, a sum of each economic indicators. The relative shifts are defined as follows:

$$\text{Relative actual shift: } RS_a = \frac{S_a}{\sum W_{ij0}} \quad (4)$$

$$\text{Relative differential shift: } RS_d = \frac{S_d}{\sum W_{ij0}} \quad (5)$$

$$\text{Relative proportional shift: } RS_p = \frac{S_p}{\sum W_{ij0}} \quad (6)$$

The computations of the relative shifts formulas 4, 5 and 6 with the NACE sections employment data of 2005 and 2018 (Table 2 at Mendeley Data, Kurek et al., 2020a) result in a single shift score for each of the examined geothermal municipality in reference to the poviat. The same procedure is conducted for the poviat and voivodeship pairs. If the value of the relative actual shift ( $S_a$ ) is positive, the employment in the geothermal municipality NACE sectors is assumed to grow faster than in the poviat. A positive score of the relative differential shift ( $S_d$ ) indicates a specific local condition that causes the increase in the employment, in our case the use of geothermal resources in the municipality. Whereas, a positive relative proportional shift ( $S_p$ ) shows the relative growth of employment in each of the NACE section. The poviats as the control group undergo the same shift-share procedure. If the results of the analysis do not repeat in the poviats, the research hypothesis is considered corroborated.

#### 4. Results and analysis

The shift-share analysis aims to find out the differences in the employment structure between the geothermal municipalities and the reference poviats. We assume that the change takes place in the services sectors and that it is related to the local geothermal resources exploitation. The scores in Table 4 depict the results of the relative shift-share analysis conducted for the pairs of municipalities, poviats and voivodeships. The relative actual ( $S_a$ ), differential ( $S_d$ ) and proportional ( $S_p$ ) shifts represent the dynamic of the NACE sectors employed population indicator. The results are presented in a comparable arrangement, therefore the shifts between the municipality and poviats are represented by the municipality shifts scores and the poviats and voivodeships are represented by the poviat shifts scores. We add as well the main geothermal activities in the municipalities e.g. a geothermal heating plant ( $p$ ), geothermal energy network supplying locally the geothermal heat and water ( $n$ ), and a geothermal recreational or health (spa) center ( $s$ ), (Kepińska, 2019).

The relative actual shifts ( $S_a$ ) is the sum of the relative differential ( $S_d$ ) and proportional shift ( $S_p$ ). The positive relative actual shift indicates the change in the employment structure of the municipality in comparison to the poviat (and the poviat to the voivodeship), whereas a positive relative differential shift explains the favorable circumstances of the employment growth. The positive relative proportional shift interprets that growing employment sectors are represented in the municipality in comparison to the poviat (and in the poviat compared with the voivodeship). The results show that the geothermal municipalities strongly outperform the poviats. The municipalities that observe the greatest shifts are: Bukowina Tatrzańska, Uniejów, Poddębice, Mszczonów, Pyrzyce and Szaflary. Their reference poviats yield opposite (negative) shifts results. Therefore, we assume stronger economic conditions for the employment growth in the geothermal municipalities than in their poviats.

The positive results of the relative differential shifts ( $S_d$ ) are seen in each of the examined municipalities, and negative results in their reference poviats. These considerable scores indicate a local cause that stimulated the employment in the NACE sectors in the observed years. Following the hypothesis, we presume that the utilization of the geothermal resources in the municipalities triggers additional service jobs in the geothermal municipalities,

**Table 4**

Results of the shift-share analysis for the examined pairs of the geothermal municipality in relation to powiat and powiat in relation to voivodeship, in the years 2005 and 2018.

Source: Own elaboration.

Administrative unit		Relative $S_d$	Relative $S_d$	relative $S_p$	Geothermal activity*
municipality	Uniejów	0.959	0.810	0.149	<i>p,n,s</i>
	Poddębice	0.302	0.116	0.186	<i>p,n,s</i>
powiat	Poddębicki	−0.148	−0.039	−0.109	
	Mszczonów	0.126	0.066	0.060	<i>p,n,s</i>
powiat	Żyrardowski	−0.157	−0.140	−0.016	
	Szaflary	0.158	0.181	−0.023	<i>p,n,s</i>
powiat	Nowotarski	−0.094	−0.126	0.032	
municipality	Bukowina Tatrzańska	0.978	1.167	−0.189	<i>p,s</i>
	Zakopane	−0.157	0.012	−0.170	<i>p,n,s</i>
	Biały Dunajec	−0.104	0.004	−0.108	<i>n</i>
	Poronin	−0.096	0.014	−0.109	<i>n</i>
powiat	Tatrzański	−0.076	−0.155	0.080	
	Stargard	0.096	0.033	0.064	<i>p,n</i>
powiat	Stargardzki	0.085	0.076	0.009	
	Pyrzyce	0.161	0.041	0.121	<i>p,n</i>
powiat	Pyrzycki	−0.087	−0.037	−0.050	

\*p- geothermal plant, n- geothermal municipal network, s- geothermal spa/ recreational center

that are not present in the powiats. We relate this performance with the scope of new services related mainly to the establishment of the geothermal recreational centers and spas. The forms of the resource utilization in each of the geothermal municipalities are presented along the shift-share analysis outcomes in Table 4. The Table 5 illustrates the differential shifts of the number of employed inhabitants in each of the group of the NACE sections of employment in Table 2. We show the differential shifts for the compared pairs of municipalities and powiats, and powiats with voivodeships (Table 3) resulting from the formula 2 computation of the employment data (Mendeley Data, Kurek et al., 2020a). The hypothesis testing concentrates on the analysis of the NACE Sections 3 and 5 contribution to the total number of differential shift for each municipality and powiat. A growth in employment absolute numbers is therefore expected in the differential shift of these sections. They represent the trade and services categories of employment according to the data provider i.e. Central Statistical Office in Poland.

In order to test if either the geothermal energy network and the geothermal recreational centers and spas contribute to the employment changes illustrated by the differential shift, we check in which economic sectors they operate. The Central Registration and Information on Business CEIDG<sup>4</sup> collects the economic activities NACE classification information on all of the registered entrepreneurship forms in Poland. The institution's database identifies the NACE economic category of a registered firm of choice. The major economic activity of the geothermal heating plant is the production and supply of heat and hot water, the NACE section D and E (water treatment and delivery). Whereas the classification of the geothermal recreational centers is the NACE section R (sport, entertainment and recreation), and in case of a geothermal spa — section Q (medical and spa care). The geothermal plants providing water and heat encourage the activities of the NACE section C (industrial processing) and F (construction). However next to it, accompanying businesses are expected to emerge. Since the geothermal recreational and health centers conduct additional commercial activities or can rent premises within the establishment, we performed a desk analysis of the dedicated geothermal water centers websites (Termalni, Infobasen). To verify the desk research the local geothermal specialists were consulted (see Acknowledgments). Using the CATI (Computer Assisted Telephone Interview) survey,

the phone interviews were conducted using supporting software. The method ensures a high quality of the data collection since the interviewer is guided by the questions and interpretation errors are avoided. It is also a time optimizing method. As a complementary technique the CAWI (Computer Aided Web Interviewing) was run. The CATI and CAWI methods of data collection from a sample of individuals provide a systematic and bias reduced approach in the opinion of Lee and Malhotra (2006) and Barbu and Isaac-Maniu (2011). The local geothermal specialist were asked a series of questions regarding the economic activities that emerge locally related to the geothermal centers. Based in the collected information the NACE categories were matched using the CEIDG online catalogue. The experts were supplied with additional questions regarding the general economic condition of the municipalities.

The findings of the desk research and the experts interviews point out additional bundled services emerging along the geothermal spa and recreational centers. According to the NACE categories following employment sectors expand: hospitality and gastronomy (section I), beauty and hairdressing treatments (section S), rehabilitation treatments (section Q), retail trade (section G), sports equipment rentals (section N), event organization services (section R) and households producing goods (T). Therefore, the employment change represented by the differential shift result is associated with the group 3 (trade and services: NACE sections G,H,I,J), and the group 5 (other services: NACE sections M,N,O,P,Q,R,S,T,U), in Table 2. No other commercial establishments in the municipalities that indicate the same NACE categories were identified throughout the CATI and CAWI research, nor the desk research. The NACE groups are already merged in the database of the Local Data Bank. We examine the differential shifts of both, the geothermal municipalities and powiats, resulting from Table 3 pair comparisons. Following the differential shift results in Table 5, the dynamics of employment in the NACE group 3 and 5 answer our hypothesis that the local geothermal resources utilization leads to an increase of employment in the service sectors. If a growth in employment in both groups on the municipal level is observed, we associate it with the effect of the geothermal recreational and spa establishments.

Poddębicki powiat, Uniejów and Poddębice: both municipalities observe a large growth of the employment in the two groups of NACE sectors (3 and 5) representing trade and services. The differential shifts for the Pyrzycki powiat result negative for the same trade and services NACE sectors (3 and 5). The number of trade and services employed in the powiat largely dropped there in

<sup>4</sup> <https://prod.ceidg.gov.pl>

**Table 5**

Scores of the differential shifts ( $S_d$ ) per NACE employment sections grouped (1–5) as an outcome of the shift-share analysis for the Table 3 pairs of municipalities and poviats (I) and poviats and voivodeships (II) in 2018 compared with 2005, in number of employed.

Source: Own elaboration.

<b>I. municipality and powiat</b>		Mszczonów	Uniejów	Poddębice	Zakopane	Bukowina	Poronin	Biały Dunajec	Szaflary	Pyrzyce	Stargard
1	agriculture	–20	–13	–15	–4	–4	–18	–7	0	81	–1
2	industry, construction	295	–46	–215	–84	4	32	8	74	85	752
3	trade and services	50	173	212	543	430	48	46	15	14	–447
4	finance and real estate	28	10	92	–2	–8	14	–1	–79	102	13
5	other (incl. other services, single economic activities)	1	239	198	–374	394	–70	–45	109	–147	95
<b>total Sd</b>		254	363	273	80	816	6	1	119	134	412
<b>II. powiat and voivodeship</b>		Żyrardowski	Poddębicki	Poddębicki	Tatrzański	Tatrzański	Tatrzański	Tatrzański	Nowotarski	Pyrzycki	Stargardzki
1	agriculture	483	–554	–554	1141	1141	1141	1141	–3336	–532	–679
2	industry, construction	–1132	744	744	–143	–143	–143	–143	1121	145	2656
3	trade and services	–639	–253	–253	–2831	–2831	–2831	–2831	–1253	227	–696
4	finance and real estate	–160	–25	–25	–105	–105	–105	–105	–226	–358	579
5	other (incl. other services, single economic activities)	–831	–454	–454	–114	–114	–114	–114	–1006	241	–386
<b>total Sd</b>		–2279	–542	–542	–2053	–2053	–2053	–2053	–4700	–277	1474

the tested years. Hence, the factors within the Poddebice and Uniejów municipalities stimulate the growth in the services and trade employment over the 2005 and 2018 period. We associate it with the induced services employment connected to the geothermal recreational and spa centers present in both municipalities. Fig. 2 illustrates the differential shifts values in trade and services sectors.

Żyrardowski powiat and Mszczonów: a moderate growth of employment in the trade and services sector of the group 3 and 5 takes place between the 2005 and 2018. The trade and services growth is related to the presence of the geothermal recreational establishment in the municipality; especially the hospitality and food establishments with other single recreational and commercial activities. Both services employment groups observe a striking decline in the powiat. Fig. 3 presents the changes in the trade and services employment according to the obtained differential shifts.

Nowotarski powiat and Szaflary: following Table 5 results for Szaflary, the trade and services sectors attract the most of the employment among the other NACE categories. Group 5 shows growth in employment, distinctly outperforming the powiat results. There are two geothermal recreational and spa centers in the municipality that cause this major employment demand in the related services sectors. The main employment trend are the services and singular economic activities that reprofile this municipality into a touristic destination. Fig. 4 depicts the differential shifts findings.

Tatrzański powiat, Zakopane, Bukowina Tatrzańska, Poronin and Biały Dunajec: The municipalities are located within the same Tatrzański powiat. The strongest results of the differential shifts in the two trade and services employment categories among all of the examined locations are seen in the case of Bukowina Tatrzańska. Two big geothermal recreational centers attract new services and economic activities that distinguishes this municipality in the Tatrzański powiat. Zakopane known to be a popular tourist destination in the Polish mountains observes a large shift in the trade and services employment (group 3). However, other services and single economic activities (group 5) decline between 2005 and 2018. The geothermal recreational establishment in Zakopane is an additional tourist amenity, not a major local economic leverage. Moreover, it is a popular tourism destinations and the service sector is already vivid there. Both municipalities Poronin and Biały Dunajec observe a comparable differential shift in the trade and services employment. Between 2005 and 2018, a slight increase in the trade and services employment (group 3) is observed with a decrease in other services and activities (group 5). Both have an access to the same geothermal heating and water network, whereas no other geothermal resource utilization form is present. Therefore, it is expected that the number of trade and services jobs are generated by the tourism demand rather than the geothermal resources developments. Fig. 5 depicts the analysis and the Tatrzański powiat losing employment in both NACE categories.

Pyrzycki powiat and Pyrzyce: the results of the differential shifts analysis point to the general growth of employment in trade and services groups in the Pyrzycki powiat, opposite to the Pyrzyce municipality where the trade and services jobs decrease (group 5) within the observed time. Fig. 6 illustrates this finding. A geothermal heating plant is the only application of the resource in Pyrzyce.

Stargardzki powiat and Stargard: In both cases the trade and service sectors (NACE group 3) declined in employment between the years 2005 and 2018. Fig. 7 observes the slight increase in the other services sectors and single economic activities (NACE group 5), an opposite trend to the powiat. As a municipal service Stargard offers geothermal heat and water to its inhabitants without further commercial application of this resource. Hence, the

service jobs in Stargard are not directly related to the availability of geothermal utilization.

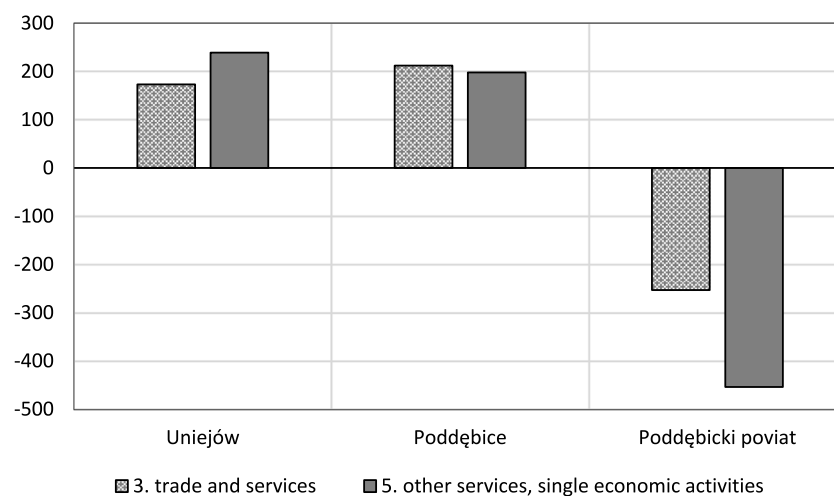
The shift-share method determines the direction of changes in the municipalities, which is then verified through the qualitative research. The analysis of the differential shifts in the NACE categories of employment in trade and services (group 3) and other services and single economic activities (group 5) shows the opposite result for the geothermal municipalities and powiats. This trend is visible especially in the municipalities with geothermal establishments. The highest number of employed persons in both services categories are found in the municipalities with at least one geothermal recreational center or spa, next to using the geothermal energy network (Uniejów, Poddebice, Mszczonów, Bukowina Tatrzańska, Szaflary). Therefore, having a geothermal establishment is considered as a local circumstance and it reveals in the positive scores of the differential shifts in the geothermal municipalities (Table 5). The municipalities without the geothermal recreational and spa establishments do not observe a considerable services jobs increase in our study. The control groups results confirm this observations. The shifts in the two services groups (3 and 5) are minimal regarding some unspecified factors of service employment occurring on the powiat and voivodeship level in the examined period of time. The geothermal utilization caused shifts impact stronger the employment structure in the municipalities. Therefore, we argue that employment in trade and services sectors has a positive contribution to the differential shift. The geothermal spas and recreational centers and the accompanying businesses contribute positively to the differential shift scores at the municipality level.

## 5. Conclusion and discussion

This research aims to find out if the local employment structure changes while using the geothermal resources. We zoomed into the ten cases of municipalities in Poland that utilize the resource. The employment data collection is limited to the years 2005 and 2018. We introduce the control groups of powiats. The NACE categories of employed population are used as the variables in the chosen method. The shift-share data analysis is applied, commonly used the regional sciences and here adopted to the local case study. The results show the compelling changes in the municipalities employment in the trade and services sectors linked with the presence of geothermal recreational and health establishments in Poland. These changes were not observed in the control pairs of powiats and voivodeships. The hypothesis that the geothermal resources utilization leads to an increase of employment in the service sector at the municipality level is corroborated. The creation of the geothermal resources based tourism is expected to generate local jobs in direct and indirect forms. It is as well justified by the strong results of the differential shift in the geothermal municipalities, that are associated with the local circumstances of employment dynamics.

Despite the economic growth in Poland between the 2005 and 2018 (IMF, 2018; Raszowski and Bartniczak, 2019), the examined geothermal municipalities observe an additional employment trigger. Our research finds out that the municipalities with a diverse utilization of the geothermal resources notice the strongest shifts in the employment towards the trade and services sectors. This trend is not found in the control group of powiats. Despite the rural typology of the municipalities, the specialization in recreation and health services emerged between 2005 and 2008. The industrial use of the geothermal resource as the heat and water provision results to be a minor factor of changes in the municipalities economic structure. The significant results of the differential shifts analysis in the trade

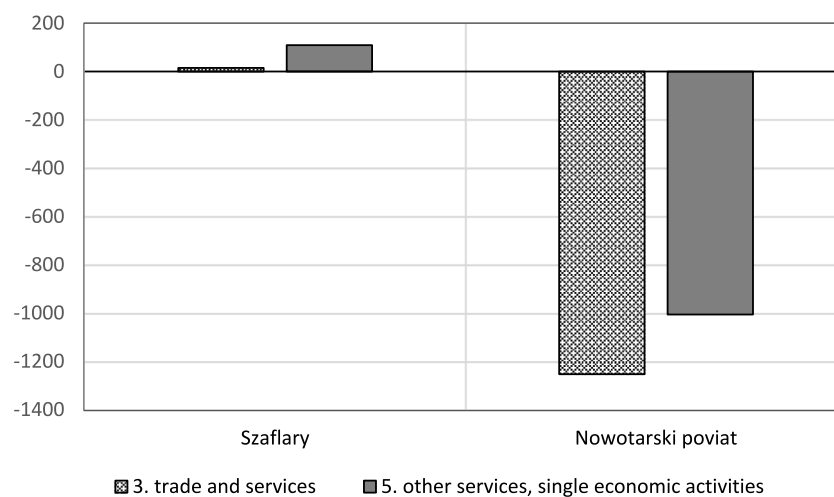




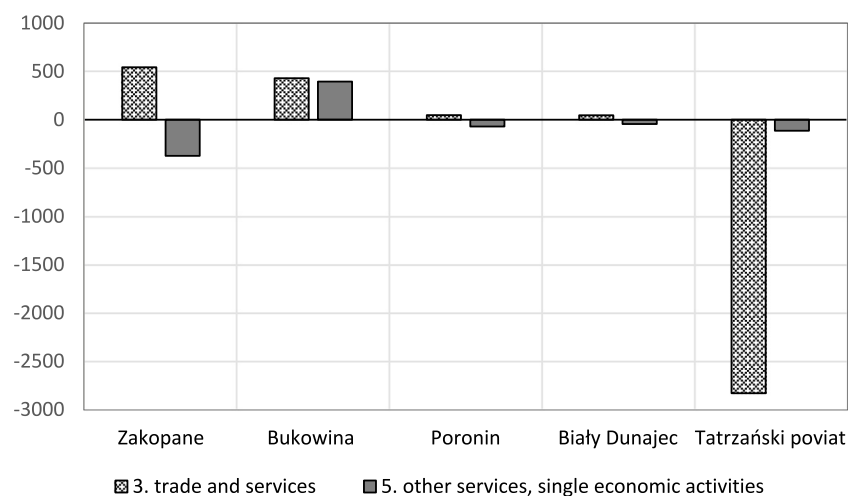
**Fig. 2.** Visualization of the differential shifts ( $S_d$ ) for the Uniejów and Poddebice municipality and Poddebicki powiat in the years 2005 and 2018, per number of jobs in the two NACE categories of trade and services employment (see Table 5).  
Source: Own elaboration.



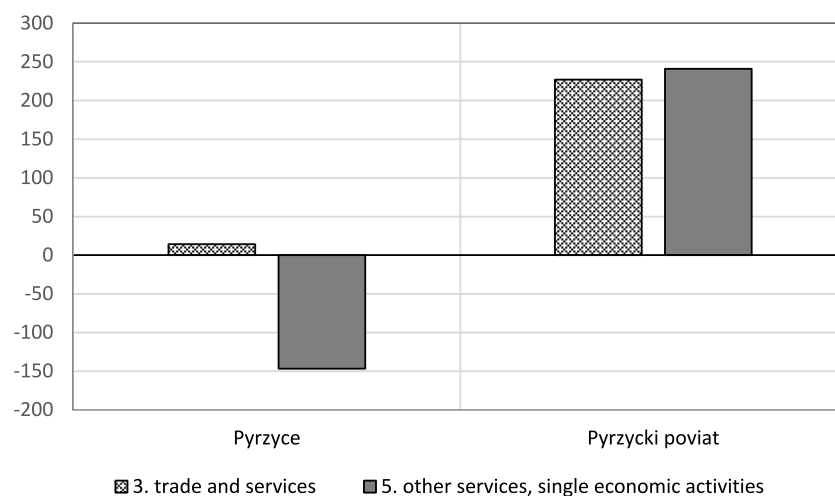
**Fig. 3.** Visualization of the differential shifts ( $S_d$ ) for the Mszczonów municipality and Żyrardowski powiat in the years 2005 and 2018, per number of jobs in the two NACE categories of trade and services employment (see Table 5).  
Source: Own elaboration.



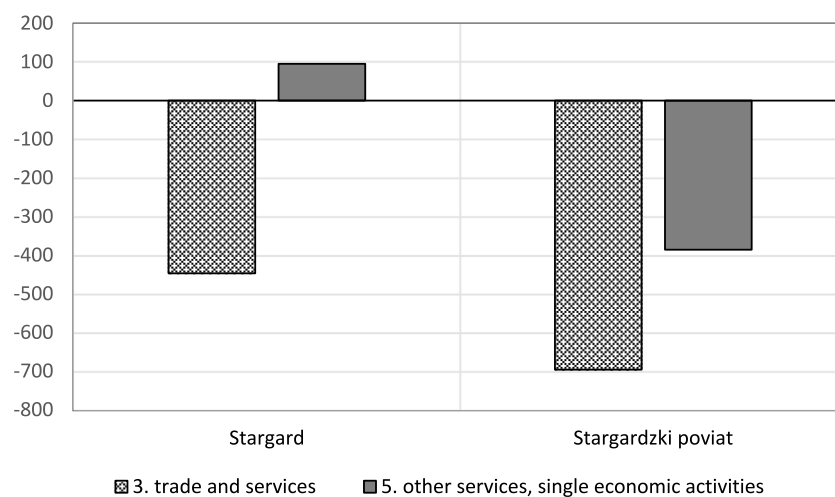
**Fig. 4.** Visualization of the differential shifts ( $S_d$ ) for the Szaflary municipality and Nowotarski powiat in the years 2005 and 2018, per number of jobs in the two NACE categories of trade and services employment (see Table 5).  
Source: Own elaboration.



**Fig. 5.** Visualization of the differential shifts ( $S_d$ ) for Zakopane, Bukowina Tatrzańska, Poronin, Biały Dunajec municipality and Tatrzański powiat in the years 2005 and 2018, per number of jobs in the two NACE categories of trade and services employment (see Table 5).  
Source: Own elaboration.



**Fig. 6.** Visualization of the differential shifts ( $S_d$ ) for Pyrzyce municipality and Pyrzycki powiat in the years 2005 and 2018, per number of jobs in the two NACE categories of trade and services employment (see Table 5).  
Source: Own elaboration.



**Fig. 7.** Visualization of the differential shifts ( $S_d$ ) for Stargard municipality and Stargardzki powiat in the years 2005 and 2018, per number of jobs in the two NACE categories of trade and services employment (see Table 5).  
Source: Own elaboration.

and services sectors (group 3: NACE sections G,H,I,J) and sectors representing services, sport, recreation, health care and single economic activities (group 5: NACE sections M,N,O,P,Q,R,S,T) are observed between 2005 and 2018 in each municipality that has the geothermal establishments. It indicates the increase of services jobs along the expansion of the recreational and spa geothermal centers in the municipalities. Since we obtain notable shift-share results in each municipality with at least one geothermal recreational or health establishment, we associate the change in the economic structure with this commercial utilization of the resource. The compared pairs of poviats and voivodeships do not observe this trend. Moreover, the results of the municipalities with solely a geothermal energy network do not show increased employment in the services sectors. Experts interviews confirm these findings.

In this article, we consider changes the municipal level through the development of geothermal energy. The assumption of the article is to link the relationship of two phenomena: economic activity caused by geothermal energy, which began in 2005, and the impact on the employment structure in the examined municipalities. The impact is proven by analyzing quantitative data using the shift-share method. Thus, it is assumed that there is a cause and effect relationship. The shift-share results are verified through interviews with local specialists and validation of the cause-and-effect relationship between geothermal activity in areas specified by NACE categories and a determined change in the employment structure. Hence, the qualitative interview made the results credible.

The dedicated reports (see: IRENA, ESMAP) show direct employment usually related to the units of produced energy. This is the commonly practiced direct jobs assessment. Our study proposes a new measuring method to evaluate the indirect employment unpaired with the energy units production. It also allows to observe if the number of new jobs are large enough to cause a structural change in the location between the examines time periods.

On the basis of the obtained results, their impact on the development of geothermal infrastructure is considerable. It is noticed that the sectoral structure in the municipality changes to such an extent that a specific economic sector may set the direction of the development. The structural change requires technical geothermal infrastructure. Research results show the importance of planning engineering works to utilize the resources. The development of a dedicated geothermal infrastructure is the basis for the economic use, e.g. the presented geothermal centers. Expanding the attractiveness of a municipality is driven by the targeted use of geothermal installations in the direction of e.g. health, recreation but also other direct applications indicated by the Lindal diagram.

According to the shift-share results stronger changes are seen in the municipalities economic structure than in the cases of the bigger poviats. Therefore, the geothermal resources exploitation especially in small localities can play a role of a local engine of growth or at least a new specialization opportunity. Especially Uniejów, Bukowina Tatrzańska and Szaflary with a large geothermal spas business are now considered in the public opinion as the new tourist destinations in Poland (Dej et al., 2014; Dryglas and Hadzik, 2016; Halaj, 2015). The geothermal recreational and health establishments induce tourism, trade and accompanying economic sectors observed a growing employment demand. In the bigger local economies such as in Zakopane, Stargard, Pyrzyce the geothermal related activities are not a major economic impulse. If, it is one of the market factors among other predominant. The differential shift adopted as an indication of the geothermal effect in the municipality employment structure leads to considerably strong results in our study, opposite to the control group

of poviats. This observation allows to open a further discussion about the benefits of geothermal based clusters of economic activities. The intensification of geothermal economic activities can benefit from the service sector potential. In fact, the study of Czaplicka-Kotas et al. (2020) reviews the energy cluster capacity for the Geotermia Podhalańska S.A. and the municipalities that use its geothermal network. The study underlines the need for the urban symbiosis based in the green geothermal energy. Nevertheless, the development of a cluster can further induce economic activities. On the other side, the geothermal cluster concept addresses the principles of the location theory. The stimulating role of geothermal centers to the local economy can attract related businesses. Therefore, considering the obtained results, our study establishes an argument for the expansion of the use of geothermal resources locally in Poland.

The geothermal energy is foreseen with future infrastructure expansion including the power production. The effectiveness of geothermal technologies enhances larger scale of the resources application argue Moya et al. (2018) and Kumari and Ranjith (2019). Advance applications of the geothermal energy production continue to develop (Ghazvini et al., 2019), also towards storage options (Wang et al., 2018). Moreover, geothermal technologies adjusted for district heating improve substantially (Weinand et al., 2019), reaching more beneficiaries of the geothermal energy. The technological advancements of the geothermal resources are expected to popularize the use geothermal resources. It create further social value locally since we argue in this article that geothermal induces additional economic sectors, accompanying the energy production. Hence, it is important to invest in technologies that increase the use of geothermal energy locally.

#### CRedit authorship contribution statement

**Katarzyna A. Kurek:** Writing - original draft, Conceptualization, Investigation, Software. **Wim Heijman:** Methodology, Supervision. **Johan van Ophem:** Writing - reviewing and editing, Conceptualization. **Stanisław Gędek:** Data curation, Visualization. **Jacek Strojny:** Validation, Investigation.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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