energies

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The Economic Situation of Polish Cities in Post-Mining Regions. Long-Term Analysis on the Example of the Upper Silesian Coal Basin

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Abstract: The purpose of this article is to identify the long-term economic consequences of mine decommissioning for five selected cities located in Poland in the Upper Silesian Coal Basin. It is carried out over a period of 18 years and covers the period 2003–2020. The economic effects of decommissioning are examined in the context of the budgets of cities where mining plants were closed. In the course of the analyses, the authors of the article attempt to answer the following research questions: (1) has the decommissioning of the mines influenced the current and strategic situation of the examined cities in terms of their budgets? (2) Have the examined cities felt the economic effects of mine decommissioning in a similar way? The assessment of the economic effects of mine decommissioning was carried out from the following two perspectives: (1) operational, relating to the balance of local budgets, and (2) strategic, taking into account the level of long-term liabilities of the examined cities. As part of the research methodology, budget analysis, descriptive statistics, dynamics and trends analysis, correlation and comparative analysis were used. The research carried out in the article shows that the decommissioning of hard coal mines in the examined cities of the Upper Silesian Coal Basin had a negative impact on the balance of local budgets and the level of long-term debt. This was especially true in the cities where all the mines had been decommissioned and which had no way of replacing the mining industry with other economic alternatives. The cities with more diversified economic activity and sources of income were in a better economic condition.

Keywords: coal-mining liquidation; post-mining regions; economic effects of the decommissioning of mining enterprises; post-mining cities

Citation: Jonek-Kowalska, I.; Turek, M. The Economic Situation of Polish Cities in Post-Mining Regions. Long-Term Analysis on the Example of the Upper Silesian Coal Basin. *Energies* **2022**, *15*, 3302. https://doi.org/10.3390/en15093302

Academic Editor: Nuno Carlos Leitão

Received: 3 April 2022
Accepted: 28 April 2022
Published: 30 April 2022

1. Introduction

The activity of mining enterprises, unlike many other economic entities, is temporary in nature, determined by the geological sufficiency of deposits and the economic profitability of extraction [1]. After the mining enterprise ceases to operate, it is decommissioned, but the effects of its activities may be felt even in several decades. In the literature on the subject and in practice, the environmental consequences of the decommissioning of mining enterprises are most often reported and include the following: serious hydrological disturbances, surface deformation and water and air pollution [2,3]. Spontaneous fires at mining waste landfills pose a significant problem. They hinder the rehabilitation of post-mining regions and pollute surface and ground waters [4]. Their levelling and elimination are extremely time-consuming and cost-intensive, due to the scale and scope of mining enterprises' operations. Nevertheless, as emphasized by Jiao et al. (2020)—studying the transformation paths of Chinese post-mining cities—the pursuit of these cities towards environmental sustainability is possible and achievable [5]. However, sustainability and the natural environment should be taken care of during the extraction period [6–8] because such an approach can only effectively prevent the shrinkage of post-mining cities after the decommissioning of mining enterprises.

Another problem in post-mining regions is spatial planning and the integration of post-mining architecture into the landscape of a modern city [9–11]. A common solution to this issue is the use of post-mining infrastructure as post-industrial tourism facilities [12,13], but not always and not everywhere. As emphasized by Krzysztofik et al. (2020), in the economies of Central and Eastern Europe, an additional obstacle to the transformation of post-mining cities is the post-communist architecture and the changing needs of local communities and the decisions of local authorities, regarding the direction of urban space development [14,15]. The infrastructure of these cities presents a wide variety of architectural styles, making it difficult to integrate post-industrial tourism facilities. The ubiquitous monumentalism—typical of the socialist realist era—overwhelms the remaining buildings and makes it difficult to embed the newly created structures into the existing architecture. In such circumstances, planning and creating visible, visually attractive tourist infrastructure poses a challenge.

The decommissioning of mining enterprises also causes serious socio-economic effects [16,17]. They are associated with the loss of many jobs in the region, and often also with the collapse of the region's key economic sector [18]. This, in turn, reduces the income of the local community, as well as the budget revenues of local governments. In extreme cases, the end of exploitation may cause the pauperization of the entire region and its residents. An example of such serious consequences can be found in Malawi (Africa), where the closure of mining brought a dramatic reduction in the income of the population and caused mass migration [19]. The negative impact of mine closures is also noted in India (Asia), where the difficult economic situation is not conducive to strategic reorientation, and the possibilities of diversifying the income of the population are very limited [20]. Another example of a problematic situation is found in Namibia (Africa), where 250 decommissioned mines have been left standing without plans for reclamation of the post-mining areas. The effects of decommissioning pose a serious threat to the health and life of the local community, which, for economic reasons, accept and need mining companies [21].

In this kind of situation, it is extremely important to look for alternative development paths that would make it possible to fill the income and industrial gaps resulting from the decommissioning of mining enterprises. The earlier the region's authorities plan and implement remedial actions, the smaller the scale of the side effects related to the end of mining operations will be [22–25]. As the research of Martinat et al. (2016) shows, the residents of cities where mines have been decommissioned expect local authorities to support the conversion of post-mining areas for other economic purposes (e.g., economic zones), which allows them to replace the lost jobs in mining enterprises [26].

Yu et al. (2016) and Martinez-Fernandez et al. (2012) emphasise that, in the process of the successful transformation of post-mining cities (Yichun in China; Mount Isa in Australia; Sudbury, Canada; Yubari, Japan), a large role is played by the circular economy and the adaptation of development directions to the current and prospective environmental policies in the region [27,28]. Marot and Harfst (2021) document the above conclusion using the example of the analysis of small and medium-sized cities in Central Europe (the Zasavje region in Slovenia; Welzow in Germany; Bad Schlema in Germany), which successfully used the production of biomass or geothermal energy in the post-mining transformation [29].

The role of local and regional authorities is also of considerable importance in ensuring the current and long-term socio-economic security of mining crews, their families, and mining-related communities. Nevertheless, as Engwicht and Ankenbrand (2021) emphazise, this is a very difficult task, especially in less developed or developing economies [30–32].

Accordingly, research and analyses concerning the fate of post-mining cities are carried out in several main directions. They are holistically classified by Kretschmann (2020) [33], who refers to the decommissioning of coal mining in Germany by 2038 and the related need to prevent the negative effects of this process. In his opinion, these directions include the following:

(1) Technical issues related to geology and hydrogeology aimed at reducing the environmental effects of underground mining;
(2) Conducting geotechnical monitoring to minimise surface damage and mining damage;
(3) Protection of post-industrial heritage associated with coal mines;
(4) Planning economic transformation of post-mining regions aimed at ensuring the highest possible quality of life for future generations living in post-mining regions.

In the literature on the subject, a lot of attention is paid to the first three issues [34–42]. The issue of the economic consequences of the decommissioning of mining enterprises is discussed less frequently, and most of the publications in this area are of an overview nature and analyse the economic consequences for local communities. The most frequently used research methods in this area are case studies or questionnaire studies. For these reasons, the authors of this study analyse the financial consequences of the decommissioning of mining enterprises from the perspective of the budgets of post-mining cities.

Bearing in mind the circumstances described above, the purpose of this article is to identify the long-term economic consequences of mine decommissioning for selected cities in the Upper Silesian Coal Basin in Poland. It is carried out over a period of 18 years and covers the period 2003–2020. The economic effects of decommissioning are examined in the context of the budgets of cities where the mining plants were closed. The research considered the cities where mine closures were the highest during the research period. This made it possible to observe the long-term socio-economic effects of the process. Moreover, sample selection increased the probability of linking and explaining the changes in the analysed cities against the liquidation of the mining industry.

In this context, the authors of this article attempt to answer the following research questions: (1) has the decommissioning of the mines influenced the current and strategic situation of the examined cities in terms of their budgets? (2) Have the examined cities felt similar economic effects of mine decommissioning?

Research from the presented perspective and scope has not been conducted so far, and their results contribute to the resource economy in the following fields:

- Evaluation of long-term economic impact of mine liquidation for cities' budgets (the budgetary approach has not been presented in the literature on the subject so far);
- Detailed analysis of the financial situation of cities in the post-mining phase, which is not a descriptive case study (the most common way of presenting the situation of post-mining cities);
- A comparative analysis of the towns in the post-mining areas, carried out in order to identify the possibilities of halting the negative consequences of mine liquidation (indicating effective business reorientation paths in order to avoid economic crisis and pauperisation);
- Highlighting the consequences of neglecting to plan for urban development in the post-liquidation period (especially relevant for emerging and developing economies that currently benefit from the mining industry);
- Highlighting the need for advance planning of measures to prevent economic and social pauperisation of post-mining regions.

It is worth emphasising that, apart from their contribution to the development of mining economics, the authors' research is justified and has practical significance. There are still many hard coal mines in the region referred to in the article as the Upper Silesian Coal Basin. Some are already undergoing liquidation, while others will be closed in the next several years. The assessment of the economic effects of mine decommissioning in this region will allow city authorities to better understand and prepare for upcoming strategic reorientation and to anticipate the negative impacts of mining decommissioning on the local community and city budgets.

The assessment is imperative in the context of the current environmental policy of the European Union. The progressive decarbonisation and the suspension of public assistance for the hard coal mining industry intensified the process of decommissioning coal mines in Poland. Notably, the Polish energy industry primarily uses hard coal, which means

that local communities and municipal authorities will have to bear a severe impact due to liquidating mining enterprises [43].

The following part of the article presents the adopted research methodology, including the principles of selecting cities subject to a broader analysis. Then, the decommissioning of hard coal mines in five selected cities is described in the context of their budgetary situation. In the conclusion, diagnostic conclusions and recommendations for the improvement of planning the transformation of post-mining cities are formulated.

2. Literature Studies

Mining is developing in many areas of the world. The main benefit of this development is the acquisition of energy resources and metal ores used in many branches of modern industries [44,45]. Local economies participate in the development of the mining industry, both directly and indirectly. Taxes and fees contribute directly to local government budgets. Furthermore, indirect benefits are associated with the creation of jobs and bolstering the income of local communities. For emerging and developing economies, mining can represent an opportunity to accelerate economic development [46,47].

Studies in Romania and Serbia show [48] that it is possible to achieve economic, social and environmental goals in a sustainable way, despite the highly annoying burden of mining. Nevertheless, this approach requires advance planning and the involvement of local and national authorities. The authors emphasise the importance of mining for local and state budgets. The taxes of mining companies in both analysed countries are an important source of revenue and contribute to economic development, which is very important for emerging countries [49].

The above observations are confirmed by research conducted in Kazakhstan [50]. Revenues from the mining industry significantly affect the level of national production and economic growth. They also have a positive impact on employment in the Kazakh economy. Therefore, the abandonment or liquidation of this industry would be a serious loss and hindrance to the development of this country.

It is also worth adding that modern theoretical economic models confirm the great importance of natural resource production in total production income. This has also been pointed out by Sadik-Zada et al. [51]. However, an in-depth analysis of the impact of the mining industry on production and development by Sadik-Zada (2020) indicates that, in order to achieve the economic benefits of natural resource extraction, it is necessary to reinvest the revenues generated by the industry, rather than redistribute them to the local community [52].

Nevertheless, as emphasised in the introduction, the activities of mining companies have a limited time horizon, which means that each mining region will one day become a post-mining region and will face problems characteristic of the post-mining phase [53–56].

The analysis of the literature on the subject indicates various possibilities for transforming the operations of post-mining cities [57]. One of them—probably the most attractive in terms of image—is the creation of post-industrial tourist solutions on the basis of the existing mining infrastructure. Cities in Poland, such as Tarnowskie Góry (silver mines) or Zabrze (coal mines), are good examples of such solutions, as it is now possible to visit sections of their above- and underground mines, e.g., the Black Trout (Czarny Pstrąg) Adit, the Guido Mine and the Luiza Adit. Thematic villages referring to mining traditions and customs can also be created in post-mining towns. An example of this solution is the village of Piła Młyn [58], located in northwestern Poland, which used to be a lignite mine. Currently, it is an agricultural town much less associated with the mining industry, which indicates the possibility of a fundamental change in the image and nature of a mining town.

The post-mining areas can also be used for completely different purposes. An example is a small Polish town Radzionków [59], where the area of a lignite open-pit mine was transformed into a botanical park. It is a spectacular example of using the land of a decommissioned mining company to create ecological green areas. This approach not only increases the usefulness of mining infrastructure, but also strengthens the image of mining

as an industry that has the potential to operate in a sustainable manner. Other examples of pro-environmental use of post-mining areas include agricultural or forestry goals. To quote, such operations were undertaken in Huainan, Anhui Province, China [60] or in Québec, Canada [61].

Research conducted in Finland on a larger sample of 51 mines showed [62] that most of the post-mining areas resumed cultural or recreational functions, which is also confirmed by the cases cited above. About one third of the post-mining areas were assigned new business goals. Interestingly, some of the liquidated mines were reopened for mining. The research author also draws attention to the necessity of an individualised approach to each decommissioned mine, considering its location, type of remaining infrastructure or socio-economic environment, which again emphasises the necessity of a careful and long-term approach to the liquidation of mining companies.

National and regional and local authorities play a key role in this process. Their will and strength will determine the course of the post-closure phase, and thus the extent of the negative consequences of the cessation of mining. The primary tasks of the government described in the literature include the following [63–70]:

- Conducting negotiations with mining companies, including setting the rules for decommissioning, with particular attention to financial and environmental issues.
- Establishing the legal framework for the operation of the mining industry in the country and regions.
- Mediating contacts between the local community and mining companies.
- Planning the development of the city, in terms of the different phases of the life of a mining enterprise.
- Preventing the negative effects of mine closures.

Notably, the cities in developed economies cope much better with the above tasks. They have much greater bargaining power in negotiations with the mining industry. They also have more experience and knowledge. In emerging and underdeveloped economies, the operations of mining companies are often accompanied by corruption and human rights violations. An example is the mining industry in Sierra Leone (Africa), where there is a systematic degradation of the environment and exploitation of the local community, tolerated by corrupt state authorities [71]. Similar abuses are described by Sternberg (2020) using Kyrgyzstan as an example, where local and state authorities accept predatory mining, environmental pollution and endangering the lives and health of local residents, in exchange for private and economic benefits resulting from the activities of mining companies in the region [72]. In contrast, the acceptance of mining activities by the local community in Kapunda (Australia) can be cited. The experience of previous years of sustainable mining and the responsible approach of the authorities to the needs and rights of local communities contributed to the positive attitude of local residents to restart mining in this region [73].

Finally, it is worth mentioning that the individualised approach to mine decommissioning means that research on this process is most often conducted as case studies [74–77]. Therefore, it is possible to present in detail the conditions of decommissioning of a given site, the effects of decommissioning and the possible paths of transformation of the post-mining area. Sometimes, the case studies are grouped as part of a given mining region, which also allows for comparative analysis and ranking of the proposed solutions [78,79]. Statistical studies based on a large research sample, using more advanced methodological tools, are presented much less frequently. This circumstance was an additional premise for the research presented in this article, based on the analysis of a long-term time series relating to the economic situation of Polish post-mining towns.

3. Materials and Methods

3.1. Selection of the Research Sample

As already mentioned, the research was carried out on the example of cities located in Poland in the Upper Silesian Coal Basin (USCB). The USCB is situated in the south-western part of Poland. Its total area is 7.25 thousand km^2, of which 5.65 thousand km^2 is located

in Poland. Mining has been conducted in this area for over 250 years. There are about 500 hard coal seams in the USCB, of which about 200 are currently of industrial importance (Polish Geological Institute: Geoportal).

Due to the abundance and sufficiency of hard coal deposits, the USCB has been one of the most industrialised regions of Poland for many years, despite the fact that the economic importance of mining enterprises has been systematically declining. Currently, the following two state owned mining enterprises operate in the area of USCB: Polska Grupa Górnicza (PGG), focused on the extraction of thermal coal, and Jastrzębska Spółka Węglowa SA, producing mainly coking coal. In the selection of cities for further research, only those entities in which there are or were operating hard coal mines were taken into account. This is due to the increased risk of decommissioning of these mines, due to EU environmental restrictions related to the need to decarbonise the energy sector. Table 1 presents a list of thermal coal mines, together with the cities in which they operate or operated. In addition, the table also includes the date of plant establishment under the indicated name and the date of decommissioning, if this has already taken place.

Table 1 shows that, in the cities of Bytom, Katowice, Knurów, Piekary Śląskie, Ruda Śląska, Rybnik, and Zabrze, most hard coal mines are still in operation or used to operate (from 2 to 5). Due to the fact that the article describes the economic effects of decommissioning mines, the research only includes the cities in which they were completely or partially decommissioned. These are as follows:

- Bytom: decommissioning of all 5 mines;
- Katowice: decommissioning of 2 out of 4 mines;
- Piekary Śląskie: decommissioning of all 2 mines;
- Ruda Śląska: decommissioning of 2 out of 4 mines;
- Zabrze: decommissioning of all 2 mines.

It follows from the above information that the decommissioning of mines in the widest scope concerned Bytom, the neighbouring Piekary Śląskie and Zabrze. In these cities, all hard coal mining plants extracting thermal coal were decommissioned. Two out of four mining plants still operate in Katowice and Ruda Śląska.

At this point, it is also worth adding that in the analysed research period covering 2003–2020, the decommissioning processes are primarily related to the permanent loss of profitability of mining and subsequent attempts to restructure the Polish hard coal mining industry. Currently, their intensity is additionally increased by the ban on granting public aid to the mining industry and the systematic abandonment of the use of coal in the power and heating sectors.

3.2. Data Sources, Stages and Research Methods

The research used data collected by the Polish Ministry of Finance on budget revenues and expenses of cities and the level of their debt from 2003–2020.

The analysis was carried out in the following research stages:

(1) Assessment of the current situation of cities in the context of the achieved budget surplus/deficit in relation to the value of total budget revenues, illustrating the financial operational sufficiency of the analysed cities;
(2) Assessment of the strategic situation in the context of total liabilities in relation to total budget revenues, reflecting the existing and potential development opportunities of the examined cities;
(3) Comparative analysis of the examined cities using descriptive statistics (arithmetic mean, minimum, maximum, and standard deviation), analysis of trends and correlation (Pearson's linear correlation coefficient) for the variables listed in points 1–2;
(4) Determination of a multivariate regression function for city debt (dependent variable) including the following three independent variables: (1) the level of a city's total income (in PLN); (2) the ratio of surplus/deficit to total income (in %); and (3) the number of mines operating in the city.

Table 1. List of hard coal mines in the Upper Silesian Coal Basin *.

No.	Mine	City	Date Established	Date of Decommissioning/ Information about It
1	Piast	Bieruń	1972	in operation
2	Brzeszcze	Brzeszcze	1903	in operation
3	Bytom I	Bytom	1998	2001
4	Bytom II	Bytom	1998	2004
5	Bytom III	Bytom	1998	2005
6	Bobrek Centrum	Bytom	2005	2015
7	Centrum	Bytom	1993	2015
8	Silesia	Czechowice-Dziedzice	1860	in operation
9	Sośnica	Gliwice	1917	in operation
10	Kleofas	Katowice	1840	2004
11	Wujek	Katowice	1899	2021
12	Staszic	Katowice	1964	in operation
13	Murcki	Katowice	1769	in operation
14	Knurów	Knurów	1957	in operation
15	Szczygłowice	Knurów	1961	in operation
16	Ziemowit	Lędziny	1952	in operation
17	Janina	Libąż	1907	in operation
18	Bolesław-Śmiały	Łaziska Górne	1945	in operation
19	Wesoła	Mysłowice	1917	in operation
20	Brzeziny	Piekary Śląskie	1998	2006
21	Piekary	Piekary Śląskie	1999	2015
22	Anna	Pszów	1832	2004
23	Marcel	Radlin	1858	in operation
24	Halemba	Ruda Śląska	1957	in operation
25	Polska-Wirek	Ruda Śląska	1995	2007
26	Pokój	Ruda Śląska	1902	2016
27	Zabrze-Bielszowice	Ruda Śląska	1976	in operation
28	Chwałowice	Rybnik	1897	in operation
29	Jankowice	Rybnik	1913	in operation
30	Rydułtowy	Rydułtowy	1806	in operation
31	Siemianowice	Siemianowice Śląskie	1945	1993
32	Siersza	Trzebinia	1861	2001
33	Wojkowice	Wojkowice	1996	2006
34	Czeczott	Wola	1985	2008
36	Makoszowy	Zabrze	1906	2015
37	Jadwiga	Zabrze	1948	1998
38	Piast	Bieruń	1972	in operation

* The list includes the original name without any further organisational transformations related to the creation of multi-processing plants. Source: own elaboration.

The above research methodology allows us to analyse the variability of a given phenomenon. It also enables linear forecasting of the further course of the observed regularities. It is used in the area of budget data by Atalan et al. [80] or Niftiyev and Huseynova (2021) [81].

At this point, it is also worth explaining the possible scope of the impact of the activity of hard coal mines on the income and expenditure of cities in Poland. This impact can be direct (1) in the form of revenues to city budgets for service charges, which are the source of their own income, and (2) in the form of corporate income tax, which partially supplies city budgets. It can also be indirect and felt in connection with the partial supply of municipal budgets by the tax on natural persons employed in hard coal mines. In the event of a mine being decommissioned, the city loses the above-mentioned income, which adversely affects its annual financial result. The reduction in current income may also generate increased borrowing needs, reflected in growing indebtedness.

Mine closures can also adversely affect city spending. The growing level of unemployment, population migration and its pauperisation increase social transfers, which additionally burden city budgets and worsen the economic situation of the city.

In the context of the above regularities, while carrying out analyses, the authors of the article attempt to answer the following research questions: (1) has the decommissioning of the mines influenced the current and strategic situation of the examined cities in terms of their budgets? (2) Have the examined cities felt the economic effects of mine decommissioning in a similar way?

4. Results

4.1. Analysis of the Current Situation of Cities in the Context of Budget Surplus/Deficit

In the first stage of the research, reference was made to the current economic situation of the examined cities, by calculating the ratio of their budget surplus/deficit to annual budget revenues, which lets us assess the level of income adequacy and conduct a comparative analysis between the examined cities. The results of this stage are presented in Figures 1–5. Additionally, Table 2 presents the descriptive statistics for the analysed economic variable for all the researched entities.

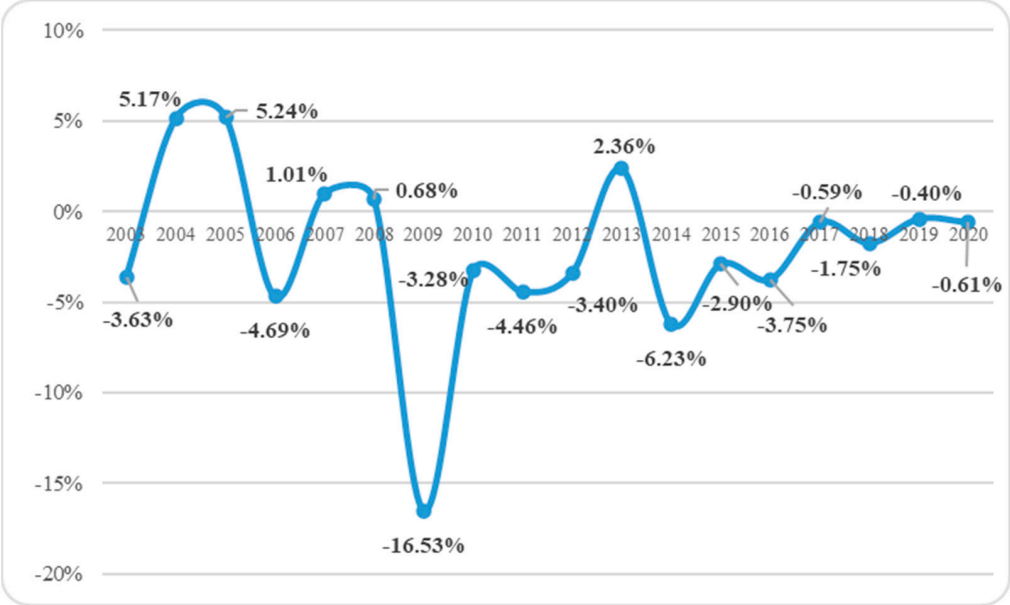

Figure 1. Ratio of the budget deficit/surplus to the annual budget revenues for 2003–2020 (in %) for the city of Bytom. Source: own elaboration.

Table 2. Statistics for deficits/surpluses of the examined cities.

City	Average	Minimum	Maximum	Standard Deviation
Bytom	−2.10%	−16.53%	5.24%	4.84%
Katowice	−0.66%	−14.68%	11.26%	7.22%
Piekary Śląskie	−0.51%	−11.05%	6.79%	5.36%
Ruda Śląska	−2.56%	−21.34%	5.25%	6.51%
Zabrze	−4.00%	−16.11%	4.94%	5.33%

Source: own elaboration.

Thus, the data for all the cities presented in the charts is highly variable over time, which is also confirmed by the values of the standard deviation included in Table 2, which indicate that relatively low average values of the ratio of surplus/deficit to budget revenues may deviate by ±5–7%.

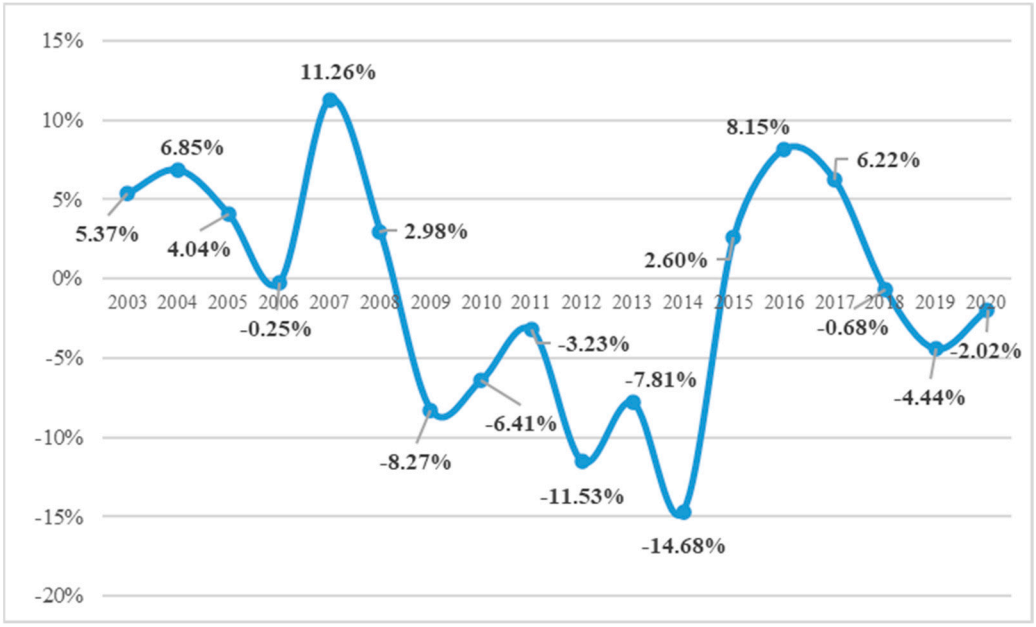

Figure 2. Ratio of the budget deficit/surplus to the annual budget revenues for 2003–2020 (in %) for the city of Katowice. Source: own elaboration.

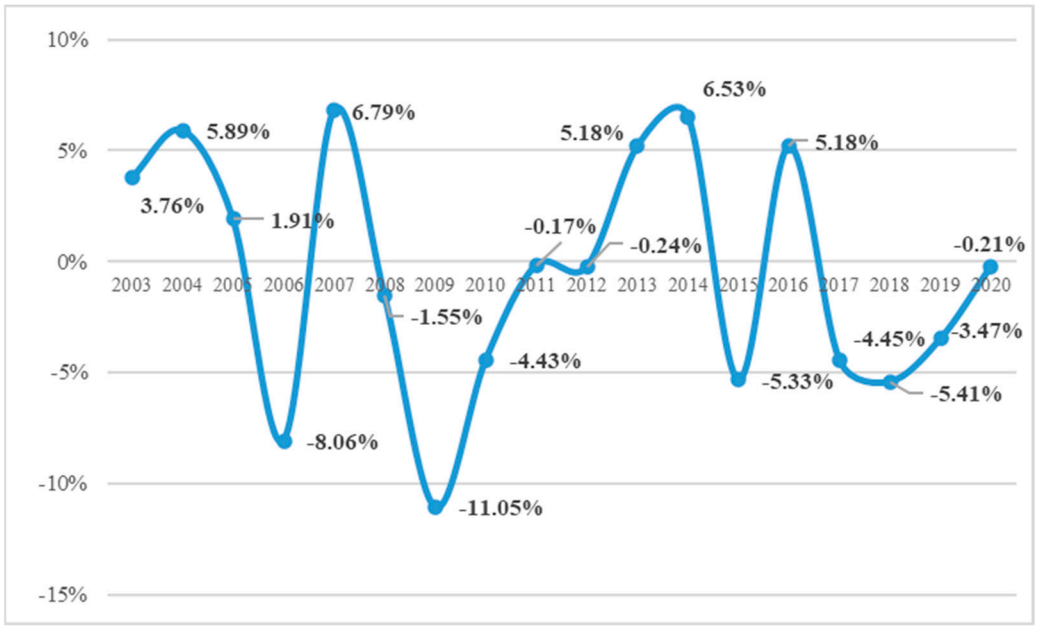

Figure 3. Ratio of the budget deficit/surplus to the annual budget revenues for 2003–2020 (in %) for the city of Piekary Śląskie. Source: own elaboration.

The data presented in the charts also indicate a certain cyclicity of the appearance of surplus/deficit, which occur several years in a row. The phenomenon may be related to the cyclical fluctuation of mineral prices and in this case, hard coal. A similar relationship is described by Niftiyev and Namazova (2020) in an article devoted to analysing the relationship between GDP and oil prices in Azerbaijan [82].

Relating the calculations presented in the charts to the periods of mine decommissioning, the following relationships for the examined cities can be noticed:

1. Bytom: all five mines were decommissioned consecutively in the years 2001, 2004, 2005, and 2015; in the initial period of the analysis, there were still temporary surpluses in the city, while the highest deficit was recorded in 2006 after the decommissioning

of three out of five examined mines; since 2009, the budget surplus only appeared once, and a year after the decommissioning of two more mines, the deficit deepened compared to the previous year, but it was not the highest in the analysed period; Bytom showed a number of deficits from 13 out of 18 of the examined years.

2. Katowice: two out of four mines were decommissioned in 2004 and 2021, respectively; in 2005, a year after the decommissioning of the first mine, there was a significant reduction in the budget surplus, which could have been caused by the decommissioning of the mine; the changes for 2021 extend beyond the analysis period; Katowice showed a number of deficits from 9 out of 18 of the examined years.
3. Piekary Śląskie: all two mines were decommissioned in 2006 and 2015, respectively; significant budget deficits appeared directly in the years of mine decommissioning; Piekary Śląskie showed a number of deficits from 11 out of 18 of the examined years.
4. Ruda Śląska: two out of four mines were decommissioned in 2007 and 2016, respectively; in the first case, no major changes were observed in the two year period after decommissioning, while a year after the decommissioning of the second mine, the deficit increased significantly; Ruda Śląska showed a number of deficits from 11 out of 18 of the examined years.
5. Zabrze: the mines were closed in 1998 and 2015; in 2015 (the year of liquidation) a high level of deficit was recorded, 1998 is longer than the period of analysis; Zabrze was characterised by the number of deficits from 15 out of 18 of the examined years.

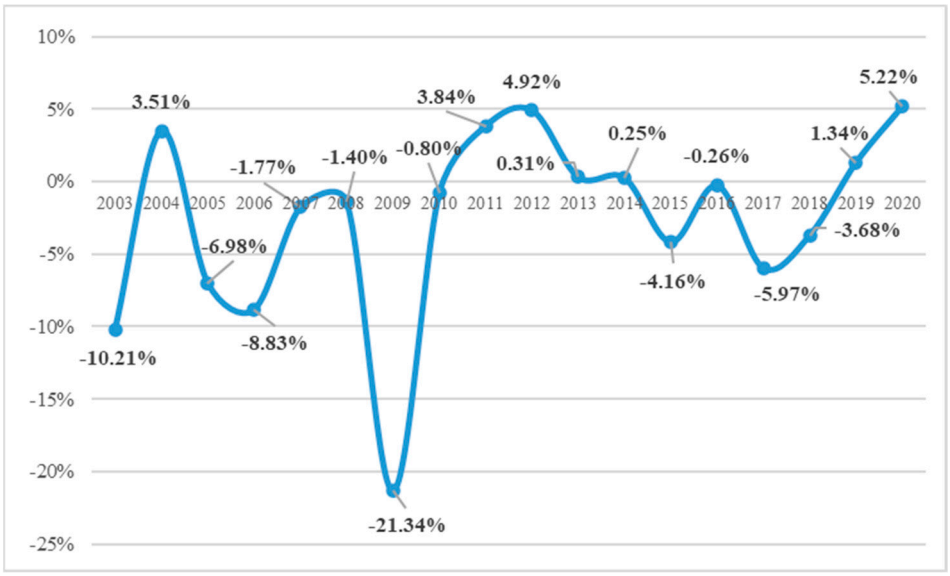

Figure 4. Ratio of the budget deficit/surplus to the annual budget revenues for 2003–2020 (in %) for the city of Ruda Śląska. Source: own elaboration.

Summarising the above observations, the following two conclusions of a more general nature can be formulated:

- An unfavourable change in the budget balance (an increase in the deficit or a decrease in the surplus) most often occurred in the year of mine decommissioning or in the following period;
- The cities where all the mines were decommissioned had a greater number of budget deficits than cities where mines still operate.

When analysing the data contained in Table 2, it can be noticed that, among the examined post-mining cities, the most difficult operational situation is characteristic of Zabrze, Ruda Śląska, and Bytom. After the decommissioning of the mines, these cities had and still have difficulties with effectively filling the resulting industrial and economic gaps. Piekary Śląskie and Katowice are in a much better situation. It should be noted here that Katowice is the capital of the province and in its area, apart from the mines, many other

economic initiatives are developing, which may certainly be the reason for better coping with the effects of decommissioning of mines. In the case of Piekary Śląskie—a typically mining city—the situation may be more favourable due to the Katowice-Pyrzowice airport being in the immediate vicinity of the city.

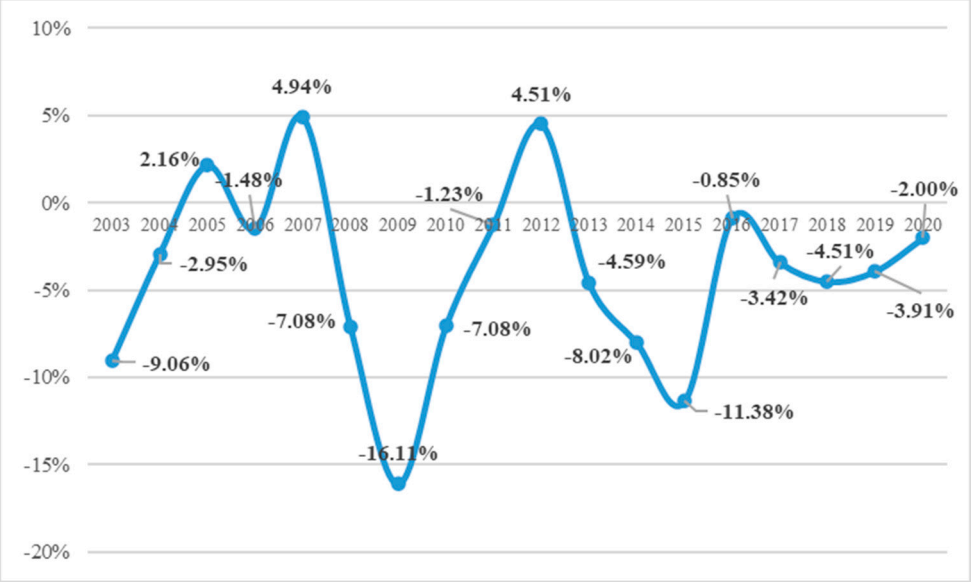

Figure 5. Ratio of the budget deficit/surplus to the annual budget revenues for 2003–2020 (in %) for the city of Zabrze. Source: own elaboration.

4.2. Analysis of the Strategic Situation of Cities in the Context of Long-Term Debt

In the second stage of the analysis, reference was made to the situation of the examined cities in the context of the relation of liabilities to annual income. The results of this analysis are presented in Figures 6–10. The descriptive statistics for the analysed variable are presented in Table 3.

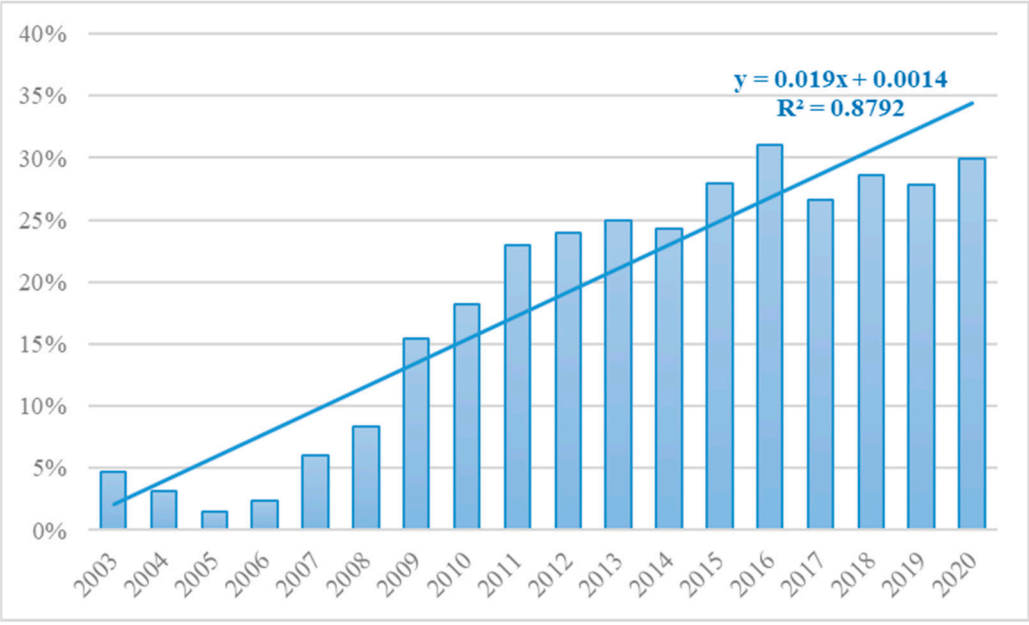

Figure 6. Ratio of liabilities to the annual budget revenues for 2003–2020 (in %) for the city of Bytom. Source: own elaboration.

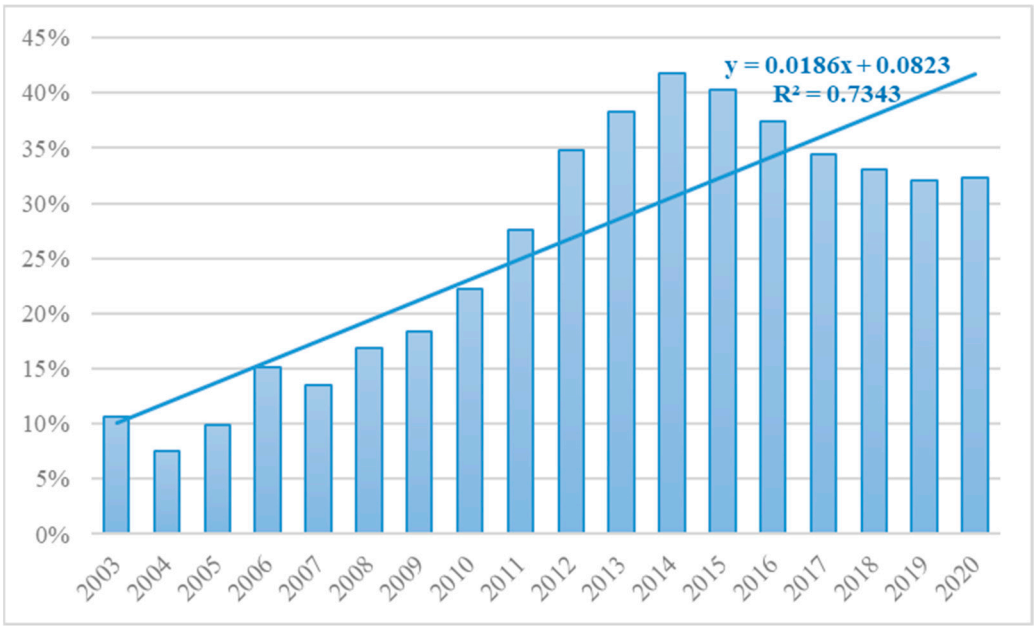

Figure 7. Ratio of liabilities to the annual budget revenues for 2003–2020 (in %) for the city of Katowice. Source: own elaboration.

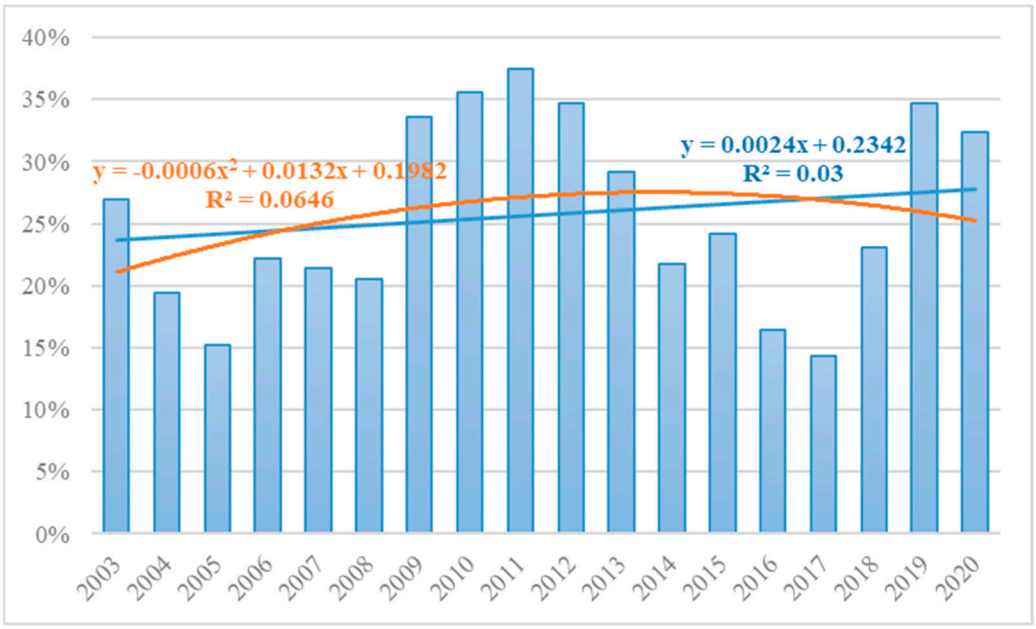

Figure 8. Ratio of liabilities to the annual budget revenues for 2003–2020 (in %) for the city of Piekary Śląskie. Source: own elaboration.

Table 3. Statistics for the liabilities of the examined cities.

City	Average	Minimum	Maximum	Standard Deviation
Bytom	18.23%	1.53%	31.08%	10.84%
Katowice	25.99%	7.53%	41.73%	11.59%
Piekary Śląskie	25.74%	14.36%	37.52%	7.54%
Ruda Śląska	31.66%	20.67%	50.69%	7.70%
Zabrze	35.82%	11.51%	68.11%	35.82%

Source: own elaboration.

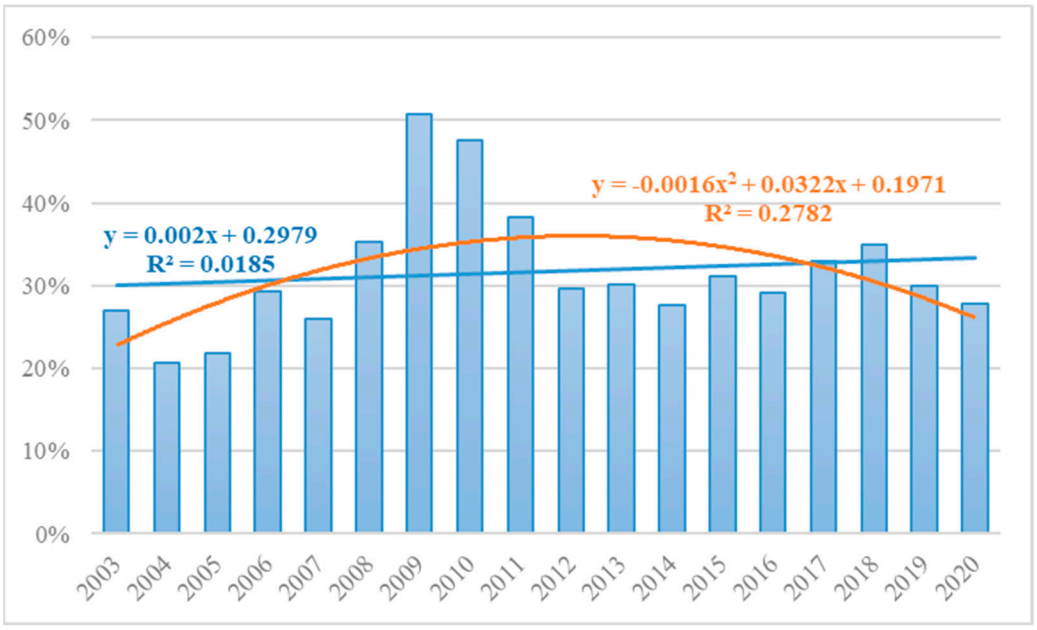

Figure 9. Ratio of liabilities to the annual budget revenues for 2003–2020 (in %) for the city of Ruda Śląska. Source: own elaboration.

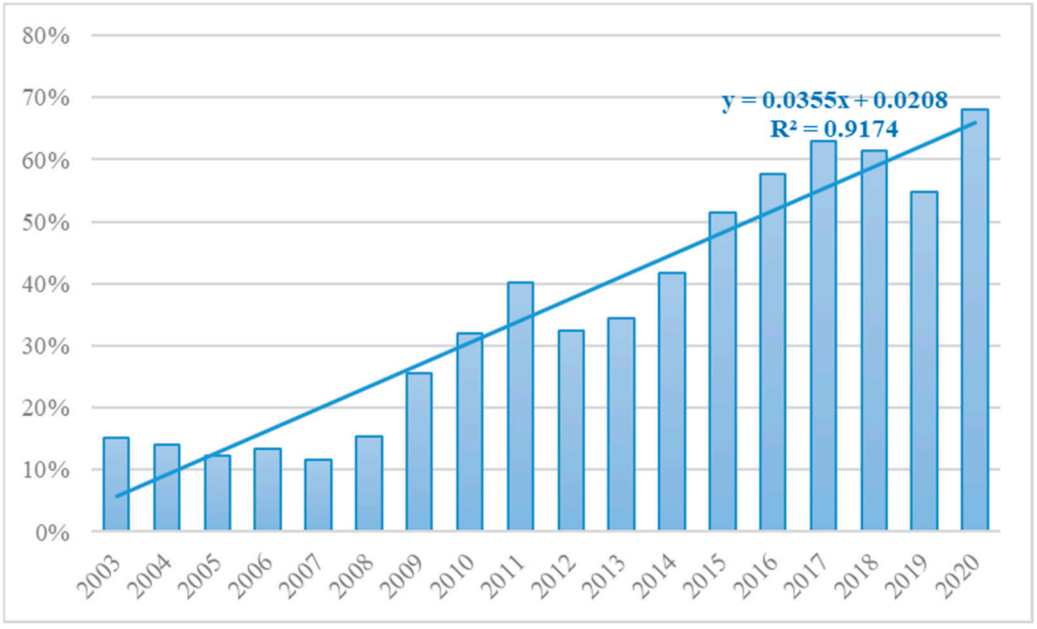

Figure 10. Ratio of liabilities to the annual budget revenues for 2003–2020 (in %) for the city of Zabrze. Source: own elaboration.

Therefore, in all the examined cities, the ratio of long-term debt to budget revenues is systematically increasing, which is confirmed by the linear growing functions of the trend. Nevertheless, they are the steepest in the case of Bytom, Zabrze, and Katowice, which means that the growth rate of long-term liabilities was the fastest in these regions. In the case of Katowice, the upward trend has clearly been slowing down since 2015. In Piekary Śląskie and Ruda Śląska, the debt increases most intensively in 2009–2013 and 2008–2011, respectively.

Nevertheless, it is important to stress that adjusting the linear trend (R^2), reflecting the upward trend in debt, is satisfactory only for Bytom, Katowice and Zabrze. For Piekary Śląskie and Ruda Śląska, the R^2 coefficient for the linear function indicates the lack of

a uniform upward trend, and the polynomial trend is a slightly better adjusted trend, although it does not reflect the debt volatility.

Despite the vague upward trend, the level of debt in Ruda Śląska was very high (Table 3), as was in Zabrze. The average for Bytom was the lowest, which means that, although the debt was systematically growing over time, its level did not cause such high financial risk as it was in the case of Zabrze. The average debt-to-income ratio for Katowice and Piekary Śląskie was similar and amounted to approximately 25%.

It is worth emphasising here that the relationships identified for all the examined cities are high and mean that the average debt ranges from 1/5 to over 1/3 of the total income. Additionally, an analysis of the maximum values shows that, in the analysed period, the debt level ranged from 31% (Bytom) to almost 70% (Zabrze). These values mean a very high financial risk, which translates into difficulties with the repayment of incurred liabilities and a significant extension of their repayment (up to several decades).

Relating the analysed data to the mine decommissioning dates, the following conclusions can be drawn:

1. In Bytom, after 3 years from the first stage of decommissioning (2001-2005), the debt was systematically increasing. There was also a significant increase in debt in 2016, a year after the second stage of decommissioning (2015).
2. In Katowice, in 2005–2006—a year after the first decommissioning—a higher level of debt was observed.
3. In Piekary Śląskie, no increase in debt was recorded in the post-decommissioning periods. In both cases (2006 and 2015), the total liabilities to income ratio decreased.
4. In Ruda Śląska, in the case of the first stage of decommissioning (2007), the debt increased in the next two years. In the case of the second period (2016), the increase in debt was not so clear and unequivocal and took place 2 years after mine decommissioning.
5. In Zabrze, in two consecutive years after the decommissioning of the mine (2015), the level of debt increased significantly.

The above-identified observations are ambiguous, as the level of debt is also influenced by many other factors, apart from the decommissioning of the mining plant. Throughout the analysed period, it was undoubtedly influenced by the need to make one's own financial contributions in connection with the implementation of EU infrastructural projects, which is typical of practically all the local government entities in Poland. Nevertheless, indirectly—in comparison to this typical tendency—it can be stated that, in the post-decommissioning periods in Bytom and Zabrze, the ratio of liabilities to budget revenues increased, which means an increase in financing risk.

In Ruda Śląska and Katowice, the observed trends were not so clear, and in Piekary Śląskie, the debt decreased relatively after the decommissioning of the mines. Therefore, in order to obtain more unambiguous conclusions, the scope of the analysed dependencies should be expanded in the future.

4.3. Analysis of Relationships between the Situation of the Examined Cities

In the last stage of the research, using Pearson's linear correlation coefficient, the examined cities were compared in terms of the analysed financial parameters, looking for similarities between their economic situations. The results of this comparison are presented in Table 4 for budget deficits/surpluses and for liabilities in Table 5.

Therefore, in relation to the current economic situation, statistically significant, positive correlations of average strength were found between Bytom, Piekary Śląskie, Ruda Śląska, and Zabrze. In the case of liabilities, statistically significant positive correlations of much greater strength were identified between Bytom, Katowice, and Zabrze. Based on the obtained results, it can be concluded that Bytom and Zabrze are in a very similar, and at the same time difficult, financial situation, both from an operational and strategic time perspective. These are typical mining cities, which for many years have focused on hard coal mining, and where it has not been possible to effectively replenish their economic potential after the closure of the mines.

Table 4. Correlation table for deficits/surpluses of the examined cities.

City	Bytom	Katowice	Piekary Śląskie	Ruda Śląska	Zabrze
Bytom	1.0000	0.4608	0.5243 *	0.5615 *	0.5765 *
Katowice	0.4608	1.0000	0.2174	−0.0862	0.2726
Piekary Śląskie	0.5243 *	0.2174	1.0000	0.5207 *	0.4422
Ruda Śląska	0.5615 *	−0.0862	0.5207 *	1.0000	0.5587 *
Zabrze	0.5765 *	0.2726	0.4422	0.5587 *	1.0000

* Statistically significant coefficient at $p < 0.05$. Source: own elaboration.

Table 5. Correlation table for the liabilities of the examined cities.

City	Bytom	Katowice	Piekary Śląskie	Ruda Śląska	Zabrze
Bytom	1.0000	0.9325 *	0.2929	0.2428	0.9297 *
Katowice	0.9325 *	1.0000	0.1651	0.1123	0.8148 *
Piekary Śląskie	0.2929	0.1651	1.0000	0.5190 *	0.1198
Ruda Śląska	0.2428	0.1123	0.5190 *	1.0000	0.1332
Zabrze	0.9297 *	0.8148 *	0.1198	0.1332	1.0000

* Statistically significant coefficient at $p < 0.05$. Source: own elaboration.

A city in a similar situation is Ruda Śląska, which shows a high level of average budget deficit and long-term liabilities; however, it differs from Bytom and Zabrze with the lack of a clear upward trend in the level of long-term liabilities. This city also did not manage to find an economic development path alternative to hard coal mining.

Katowice is in a better situation as a city in a province and Piekary Śląskie as an entity, whose development is supported by having the Katowice-Pyrzowice airport in the vicinity. In both of these cities, the level of debt is average in the studied group, and in Katowice, in the last 5 years, it has been on a downward trend, which proves the systematic settlement of liabilities and good financial condition. Katowice and Piekary Śląskie are also distinguished by a low average budget deficit.

4.4. Multivariate Regression in Assessing the Impact of Mine Closures on Urban Debt Levels

In the final step of the analysis, multivariate regression functions were identified to describe the level of indebtedness of the cities under study (ratio of total liabilities to total income). The objective of this analysis was to identify the more complex relationships between the existence of mines within the studied cities, their total income, and the ratio of surplus/deficit to total income. This will allow us to assess the strength of the potential impact of mine decommissioning on the long-term situation of the study cities.

The multivariate regression function allows us to estimate the impact of multiple independent variables (X_1, X_2, X_3, ... , X_n) on the dependent variable (Y). The function takes the following form:

$$Y = b_0 + b_1 \times x_1 + b_2 \times x_2 + \cdots + b_n \times x_n + \varepsilon$$

where:

Y is the dependent variable explained by the function;

x_1, x_2, ... , x_n are the independent, explanatory variables;

b_1, b_2, b_3, ... , b_n are the parameters that define the contribution of each independent variable to the explanation of the model;

ε is the random component, the rest of the model.

The multivariate regression model is verified by the following:

- An assessment of the statistical significance of the individual variables in the model (the analysis assumed a significance level of 0.10);
- Multivariate coefficient of determination (R^2), which is a measure of model fit and takes values in the range of <0.00; 1.00>, where a value of 1.00 means excellent fit and 0.00 means no fit;

- Corrected coefficient of multivariate determination (R_adj^2), which, similarly to (R^2), allows one to assess the model fit, but is insensitive to the number of variables and the sample size, taking values in the range of <0.00; 1.00>, where a value of 1.00 means perfect fit and 0.00 means no fit.

The dependent variable (Y) in the model is the level of debt expressed as the ratio of liabilities to total income of the city. The independent variables that could potentially affect the debt level are as follows:

- b_1 is the ratio of surplus/deficit to total income;
- b_2 is the number of mines operating in the city (changing in the year of closure of the mines);
- b_3 is the level of total income of the city, defining its current financial situation.

The results of the multivariate regression functions defined for the individual cities are presented in Table 6.

Table 6. Parameters of the multivariate regression function for the examined cities.

Cities	Parameters					
	b_0 (p)	**b_1 (p)**	**b_2 (p)**	**b_3 (p)**	**R^2**	**R_adj^2**
Bytom	−0.1086 (0.2695)	0.1616 (0.1709)	0.0693 (0.7344)	0.8267 (0.0010) *	0.8356	0.7879
Ruda Śląska	0.9372 (0.0048) *	−0.3466 (0.1436)	−1.2289 (0.0250) *	−0.9656 (0.0814) *	0.4446	0.3256
Piekary Śląskie	0.0891 (0.5504)	−0.3707 (0.1934)	0.5724 (0.3033)	0.5815 (0.2728)	0.1592	
Katowice	0.0131 (0.9486)	−0.2860 (0.0970) *	−0.0283 (0.8271)	0.6861 (0.0011) *	0.6653	0.5967
Zabrze	0.1297 (0.2622)	0.0335 (0.7116)	−0.5118 (0.0007) *	0.5230 (0.0007) *	0.8942	0.8717

* Statistically significant coefficient at $p < 0.10$. Source: own elaboration.

When analysing the data presented in Table 6, it may be observed that the debt level of the examined cities was most often and most strongly influenced by total income. For Bytom, Katowice and Zabrze, it was a positive relation, which means that an increase in total income encouraged increasing liabilities. Most probably, it resulted from the necessity of making their own contributions to EU projects, which enabled the development of urban infrastructure. In Ruda Śląska only, the relation between total income and the level of indebtedness was negative, which means that the city fell into debt to supplement the decreasing budget income. This phenomenon should be assessed negatively as, contrary to the three previously mentioned cities, in Ruda Śląska, the increase in indebtedness did not contribute to the city's development, only to satisfy its current needs.

The debt levels in Zabrze and Ruda Śląska were also negatively influenced by the liquidation of mines. The reduction in the number of mines resulted in an increase in the ratio of liabilities to total income and this relationship was statistically significant. This confirms previous observations concerning the deterioration of the economic situation of those cities in connection with the liquidation of the mining industry and the lack of alternative development paths. For Bytom, Katowice and Piekary Śląskie there was no statistically significant impact of the mines' liquidation on the deterioration of the economic situation of the examined cities, from a long-term research perspective. Katowice, as a Voivodship city, found other developmental paths, as did Piekary Śląskie.

The above conclusions allow us to conclude that mine liquidation has a significant impact on the financial condition of those cities that did not find alternative business development paths after the liquidation of hard coal mines. Such an observation clearly confirms the necessity of planning the reorientation of the city's strategy many years in advance and preparing various scenarios of the city's development in the event of the discontinuation of coal mining.

5. Discussion

The results of the conducted analyses confirm the previous conclusions about the serious economic consequences of the decommissioning of enterprises and mining plants [16–21]. Based on the considerations and research undertaken in this article, it can also be extended to the budgetary situation of cities. The results confirm the great importance of the mining industry for the economic situation and development opportunities of the studied cities [44–52]. This is particularly important for economies such as Poland, which without capital inflows are unable to make up the distance from highly developed countries [30–32].

The difficulties and problems that must be faced by the Polish post-mining cities of Bytom, Ruda Śląska, and Zabrze draw attention to the necessity of long-term anticipation of the changes in the economic structure of mining regions, as emphasised in the literature on the subject. In the analysed cases, the decisions to decommission the mines mainly resulted from the hardly predictable economic changes in the hard coal market and the socio-political conditions. The lack of remedial actions prepared in advance was not conducive to the transformation of cities, where hard coal mining was the key, and often the only, industry. The above observations confirm the previous conclusions about the problems of developing economies with the transformation of post-mining regions. Making decisions to liquidate mines for economic reasons put the studied cities in a rather difficult situation, lacking an alternative plan for business reorientation, which most likely—according to previous research results [53–56]—deepened the economic crisis of these cities. The observations made also highlight the importance of municipal authorities in the process of preventing the negative consequences of the liquidation of the mining industry [63–70].

However, it is worth adding that among the cities mentioned above, in the most difficult financial situation, Zabrze has made large and international use of the post-mining infrastructure described in the introduction for tourist purposes (the Guido mine and the Luiza Adit). It is now a major and popular tourist attraction. Nevertheless, it should be emphasised that it is not able to fully compensate for the lost jobs and lack in budget revenues. Thus, the creation of post-industrial tourism facilities may support the process of making post-mining regions more attractive [57–59]; however, it will not replace effective paths of economic transformation. The above observation also allows us to look at the image-attractive post-mining tourism from an economic perspective. In this context, it is worth noting that it cannot be the only path of transformation of the region because it is not able to fill the financial gap created after the reduction in budget revenues from the fees and taxes paid by mining companies.

None of the examined cities used the transformation paths associated with circular economy, which are presented in the current literature on the subject as effective methods of development of post-mining regions [27–29]. Moreover, old generation coal-fired boilers remain the main source of heat in many households, and city authorities have problems with replacing them with more ecological solutions. This is mainly due to the economic barriers related to the low level of personal income of the residents, but also to the habit and long-term association of coal as the natural wealth of Upper Silesia. Despite the above observations, attention should be paid to the possibility of using the paths associated with circular economy, because, as practical examples show, it is an effective and sustainable form of transformation of post-mining regions.

For the above-mentioned reasons and the obtained results of the analyses, Upper Silesian cities should be particularly recommended to plan ahead for the development of post-mining areas, especially as there are still many operating mines in the region, which will be systematically closed in the coming years, in line with the idea of decarbonisation. The lack of such an approach may result in the observed, systematic deterioration of the budgetary situation and the image of cities in which the mining industry is a key economic sector.

6. Conclusions

The research carried out in this article shows that the decommissioning of hard coal mines in the examined cities of the Upper Silesian Coal Basin had a negative impact on the balance of local budgets and the level of long-term debt. It was especially visible in the cities where all the mines were closed and which could not replace the mining industry with other economic alternatives (Bytom and Zabrze). The cities with more diversified economic activity and sources of income were in a better economic condition (Katowice and Piekary Śląskie).

Therefore, the cities whose activities are based on the mining industry should implement the following measures:

- Make attempts to diversify economic initiatives while the mining enterprises are still fully operational;
- Prepare local transformation paths years in advance, taking into account the decommissioning of mining enterprises, in such a way as to provide the residents with new jobs and prevent the pauperisation of the region;
- Incorporate the above-mentioned paths into urban strategies and multi-annual development plans, as it is impossible to change the region economically in the short term;
- Monitor the budgetary position, taking into account the operational and strategic perspectives;
- Use the best practices described in the literature on the subject (e.g., post-industrial tourism or the development of circular economy);
- Solicit regional and national support for urban transformation programmes, emphasising the importance of preventing the impoverishment of local communities.

The research undertaken in this article was carried out on the basis of general data relating to the entirety of local budgets, which is the main cognitive limitation of the formulated final conclusions. It is also notable that the state of local budgets is influenced by many determinants, not only by the functioning of mining companies, which is also a limitation of the research.

Further research and analysis on the impact of the decommissioning of mining enterprises should, therefore, take into account a more detailed scope relating to specific budget items and directly related to the budgetary revenues from the activities of mining enterprises. It is also worth relating the output of individual mines to the income to local budgets, which will make it possible to make the presented analyses more precise and detailed.

Author Contributions: I.J.-K.: literature studies, conception and research; M.T.: description and conclusions. All authors have read and agreed to the published version of the manuscript.

Funding: The research was financed from Statutory research, No. 13/010/BK_21/0057 (Institute of Economics and Computer Science, Faculty of Organization and Management, Silesian University of Technology).

Data Availability Statement: Data are available on request et corresponding author: Izabela.Jonek-Kowalska@polsl.pl.

Acknowledgments: The research was financed from Statutory research, No. 13/010/BK_21/0057 (Institute of Economics and Computer Science, Faculty of Organization and Management, Silesian University of Technology).

Conflicts of Interest: The authors declare no conflict of interest.

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