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MAPPING THE INDIRECT EMPLOYMENT OF HARD COAL MINING: A CASE STUDY OF UPPER SILESIA, POLAND[•]

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Abstract

It is insufficient to calculate the number of jobs in the mining industry to determine the labour market effects of a coal phase-out. In this paper, we estimate the scale of mining-related and mining-dependent jobs in Europe's largest hard coal mining region: Upper Silesia. In addition, we provide a precise structure and spatial distribution of mining-related companies using information from public tenders offered by five of the country's largest coal enterprises, coupled with financial and employment data from official administrative repositories. Our observations have shown a significant agglomeration effect in the region: companies within 20 kilometres of the nearest active hard coal mine were awarded 80% of all tender revenues. Moreover, we found that 41% of all identified jobs in mining-dependent companies in Upper Silesia were highly at risk of liquidation if there was to be a decline in coal production. Finally, we argue for labour market mitigation policies tailored to mining-dependent employees and the widespread application of administrative data in just transition planning to address the limitations of dominant top-down modelling approaches.

Keywords: hard coal mining, indirect employment, labour market, administrative data, Upper Silesia

JEL: L71, J21, Q43

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1. Introduction

It is insufficient to calculate the number of jobs in the mining industry to determine the labour market effects of a coal phase-out. The socio-economic contributions of mining at a regional and local level can be grouped into four categories: (1) employment, (2) district revenues, (3) welfare spending, and (4) industrial and domestic fuel (Pai, 2021). Between these categories, employment is probably the most discussed issue in mining, as the just transition to net zero without generating new social inequalities (Abram et al., 2022) is originally a labour-oriented concept (Wang and Lo, 2021).

The socio-economic contribution of mining in terms of employment can be measured on three levels:

- direct employment – the workforce employed by coal enterprises themselves,
- indirect employment –those employed at companies that produce goods or deliver services directly to coal enterprises,
- induced employment – those employed to provide goods and services to meet the consumption demand of directly and indirectly employed workers (Bacon and Kojima, 2011).

This paper focuses on the indirect employment aspect, as possessing knowledge on employment figures and the structure of mining-related workplaces is a crucial element in any attempt to understand the impact of coal mining on the broader economy or offer a viable transition pathway (Jakob et al., 2020). Indirect workplaces in firms producing goods for or delivering services directly to coal enterprises are first in line to face the consequences of a coal phase-out as their workers are more dispersed, less unionised, and poorly recognised by public policymakers compared to those with mining jobs.

The numbers behind indirect employment often vary from one source to another. These differences stem from (1) the method of measurement used, (2) the range of the mining sector, (3) the spatial and temporal scale, (4) the range of investigated multipliers, and (5) the degree of a company's dependence on mining. In the current debate about the role of mining and mining-related employment in coal regions in Europe, European Commission reports focus on the intra- and an interregional number of affected workplaces (Alves Dias et al., 2018; Mandras and Salotti, 2021) or jobs lost in the energy transition (McDowall et al., 2022), but do not specify which sectors and companies would be hardest hit. Most indirect employment studies are based on top-down Input-Output (I-O) modelling, which calculates industry linkages to study the knock-on effects caused by a change in final demand (Alves Dias et al., 2018). Such studies were applied, e.g. in Australia (Ivanova and Rolfe, 2011), Turkey (Aydın, 2018) and Germany (Oei et al., 2020). An undisputed advantage of I-O models is their relative ease of application (considering an input-output table is available) and their ability to provide estimates of indirect and induced employment through simple transformation (Bacon and Kojima, 2011).

However, using I-O modelling to calculate indirect employment has spatial, sectoral and temporal data limitations. First, aggregating the data to a national and basic sectoral level fails to detect the distribution of multiplier effects over space (Briassoulis, 1991). This makes it impossible to identify agglomeration effects (Moritz et al., 2017) and the most severely affected areas. Moreover, merging economic activity with the adopted sectoral classification may constitute a barrier to analysis. Therefore, assessing coal mining impacts requires disaggregation to detect the effects in the places where they occur. In addition, I-O tables are typically not updated yearly, and the interval between updates is several years in Europe or even more in developing countries (Bacon and Kojima, 2011). Because of this infrequency and record inconsistency, I-O modelling can miss the substitution between factors and possible replacements between inputs caused by technological changes in the long run (Christiaensen et al., 2022). Finally, in the case of mining, I-O models do not recognise regional crowding out effects from manufacturing and higher use of local services because of the wage differences between mining and other sectors (Fleming and Measham, 2014).

The scarcity of evidence on mining-related employment creates a space for expert opinions rather than objective measurement, leading to opportunities to mislead the public debate on the current role played by coal mining in regional and local labour markets. Previously, indirect employment effects of hard coal mining in Poland were measured solely through macroeconomic modelling based on I-O tables (Alves Dias et al., 2018; Kiewra et al., 2019; Frankowski et al., 2020a; Mandras and Salotti, 2021) or survey methods (Folta et al., 2015; Ingram et al., 2020). As the methodological approaches in indirect employment effect calculations seem to be a crucial challenge, we decided to fill this gap by applying a novel research method. We use the case study of Upper Silesia in Poland to address the issue and support regional policy debates on just transition processes where indirect employment must be considered.

Hence, the main aim of this paper is to estimate the indirect employment effects of hard coal mining using a novel bottom-up approach. We focus on the scale, structure, and range of indirect employment and assess the indirect impact of coal mining on the regional labour market in three steps. First, we defined a mining-related company as a firm providing goods and services for the mining industry. Second, we collected data on mining-related companies through official reporting, data scrapping, and liaising with the region's five largest coal mining enterprises. Third, we enriched this dataset with financial and employment data from official company records. Finally, we presented highly granular descriptive statistics and applied an interaction model to uncover the spatial impacts of hard coal mining on indirect employment.

We offer the following contributions. First, we explain industrial relations and indirect employment effects of hard coal mining in Poland using a bottom-up approach and novel data. We found that 41% of all identified jobs (51,200) in mining-dependent companies in Upper Silesia – primarily in manufacturing and construction – were highly exposed to the risk of liquidation should coal production decline. Moreover, we observed a significant agglomeration effect, identifying that 80% of tender revenues offered by active hard coal mines were awarded to companies operating less than 20 kilometres away. Second, we estimate the dependence of local firms on coal mining enterprises and precisely assess the relative vulnerability of local labour markets to the coal phase-out process using a spatial interaction model. This analytical approach has not been executed before in terms of an analysis of Polish coal mining. We found that distance to the closest mining site does not affect a business's exposure to limited employment or revenues. Third, we provide methodological details of the bottom-up approach and discuss its challenges, which can be helpful for researchers dealing with bottom-up measurements of indirect employment effects generated by particular industrial activities. To this end, we shared the steps to follow and improve our method and a record of the largest mining-related companies on request, which could be used for other regional monitoring systems and qualitative studies.

This paper is structured as follows: Section 2 introduces the method of measuring indirect employment effects and briefly discusses the data collection procedure. Section 3 presents the characteristics of mining-related companies and workplaces and the indirect interregional impacts of hard coal mining. Section 4 briefly discusses the results, and Section 5 summarises our findings.

2. Methods and data

This section briefly presents the input-output method commonly used to calculate the macroeconomic effects of various investments. We also demonstrate how our proposed bottom-up approach complements and extends the input-output results. Finally, we present the procedures necessary for the performance of such an analysis.

2.1. Bottom-up approach and procedure

The weaknesses of the I-O method can be overcome by applying a bottom-up approach. The advantages of this method are that it allows for 1) determining the level of companies' interdependence and thus vulnerability to demand shocks related to production decline, 2) more precise scaling of employment level and structure, and 3) the indication of the spatial concentration of surveyed enterprises.

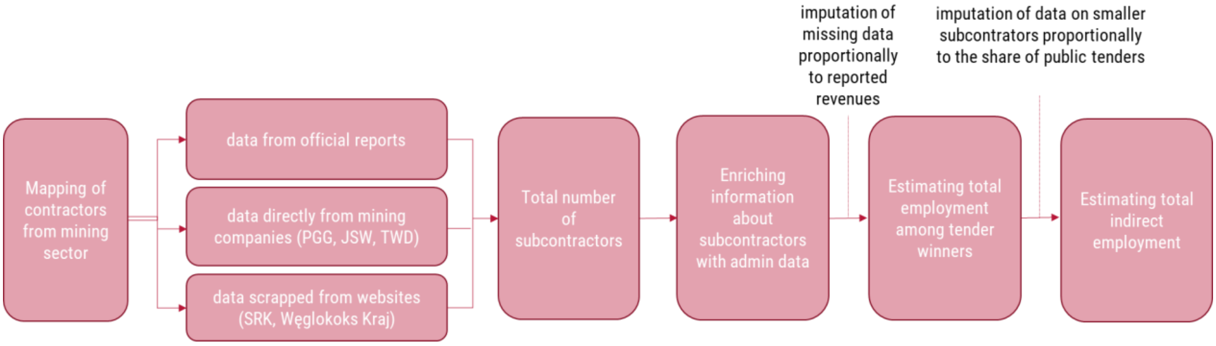
In this section, we provide our data collection procedure and measurement assumptions.

2.1.1. Data

The dataset was based on information from tenders offered between 1.07.2019 and 30.06.2021 and was obtained via an official request sent to each the region's largest mining enterprises. The information contained tender allotments, including tender number, name, contractor, and net contract value. The dataset was further extended with information scrapped from official tender portals and company reports. We also obtained detailed information by feeding our records with data from public databases (Polish Statistical Office, National Official Business Register, Ministry of Finance) and using OSINT techniques. Overall, we collected data about the legal structure, principal business activity, and location of companies fulfilling tenders for the mining industry (Graph 1).

Next, we collected the financial data available on most companies in the region with a National Court Register (KRS) number, tallying their annual net revenues from sales and the number of employees they declared in accounting reports in the last year, divided into white-collar and blue-collar jobs. In some cases, we supplemented data from these companies' management board reports. Then, we estimated their dependence on the mining sector and the scale of jobs that would be affected most based on the share of annual net revenues from sales in the last reported year (→ Appendix A2).

Graph 1. Procedure of mining-related industry data collection



Source: own elaboration.

2.1.2. Measuring indirect labour market effects

We estimated the magnitude, structure, and spatial distribution of hard coal mining's indirect labour market effects using the number of workplaces and business revenues at an industry level, which are standard units of measuring multipliers (Domanski and Gwosdz, 2010), and calculated multiplier effects for a single year (Wiedermann, 2008).

$$indirect\ jobs = associated\ workplaces + subcontractors'\ workplaces$$

$$subcontractors'workplaces = \frac{\frac{X}{(1-CF1)}}{(1-CF2)} \tag{1}$$

Where X represents data on reported employment from the National Court Register, CF_1 is the imputation of missing data proportionally to a company's revenues (7.4%), and CF_2 is the imputation of missing data on smaller mining-related companies proportionally to their revenues (38%).

We distinguished two types of indirect employment: either through companies that are organizationally associated with coal mining enterprises ("associated") or workplaces in firms providing goods and services ("mining-related"). We estimated a supplier's dependence on coal mining by dividing financial data on revenues obtained from the five largest hard coal enterprises by annual net revenues from sales made in the last reported year.[1] Due to data availability, we based our analysis on information found in official public tender documentation.

We arbitrarily define a "mining-dependent company" as a firm with at least 5% of its estimated annual revenues coming from the five largest coal mining enterprises. We classified "non-affected" workplaces as those in companies that obtain less than 5% of their estimated annual revenues from the five largest mining enterprises.[2] Companies with a share of mining revenues below the 5% threshold provided low-specialized goods and services that could be offered to a broad group of customers and branches (e.g. telecommunications services, banking services, etc.). From the point of view of mining enterprises, these services are easily replaceable.

Obtaining financial data made it possible to distinguish more detailed levels of dependence on mining industry performance. The higher the share of revenues received from mining contracts, the higher the vulnerability to declining demand in the mining industry. We introduced two degrees of this dependence based on empirical results:

1) First-affected companies obtain more than 20% of their annual revenues from mining contracts. This makes them highly vulnerable to demand decline in the mining sector and forces them to take more radical adjustment measures along with the transition.
2) Vulnerable companies obtain 5 – 20% of their annual revenues from mining contracts.

[1] Appendix A1.

[2] We present a detailed data collection and curation procedure in Appendix A2, along with our strategy for addressing data limitations in Appendix A3.

2.1.3. Spatial interaction model

We use a spatial interaction model (Kopczewska, 2013) to estimate the impact of distance from the nearest hard coal mine on exposure to the risk of job and revenue losses. In our model, we assume that flows between the indicated locations are inversely dependant to the distance i.e. the greater the distance, the weaker the flow. We use a polynomial spatial interaction model (2) which allows for the non-linearity of flows depending on spatial separation. The main explanatory variable is the distance between the units tested, measured as Euclidean distance:

$$x_i = \beta_0 + \varphi_1 D_i^1 + \varphi_2 D_i^2 + \varphi_3 D_i^3 + + \varphi_4 D_i^4 + C_i + \epsilon \tag{2}$$

where x_i is the scale of being affected by mining closure in terms of employment and revenue, φ_n is the coefficient of the distance effect, D_i^n is the distance, and C_i is the vector of controls, while ϵ is the error term.

This model allowed us to determine how the distance between a mining site and a subcontractor affects their exposure level to the risks of negative labour market impacts.

3. Results

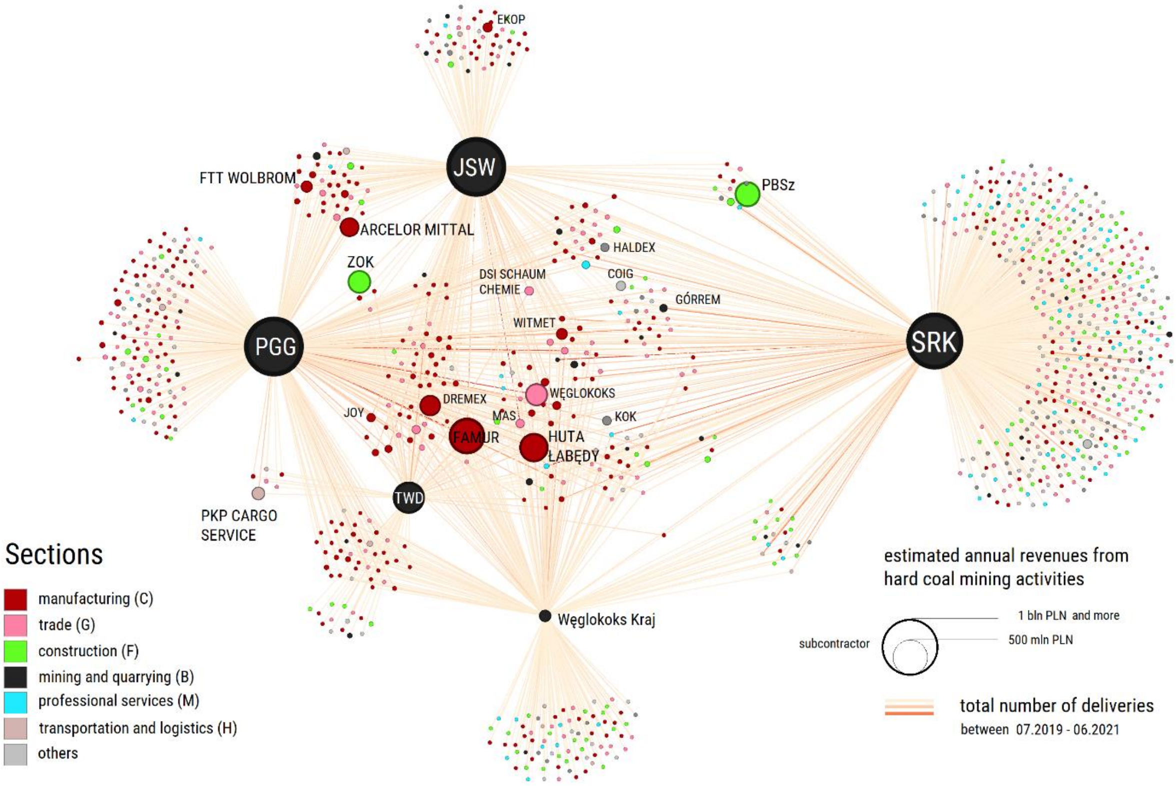
First, we present several descriptive statistics concerning mining-related companies in general. Next, we identified the network of mining-related companies and estimate their business revenues (Section 3.1.1.) and employment structure, broken down into white- and blue-collar jobs (Section 3.1.2). We then apply the aforementioned spatial interaction model to estimate the range of indirect spatial impact of hard coal mining (Section 3.2).

3.1. Descriptive results

3.1.1. Mining-related companies

The mining-related sector in Poland is highly concentrated. We identified 1,054 mining-related companies that directly cooperated with coal enterprises in Upper Silesia during our analysis period (07.2019–06.2021). The top 2% of mining-related companies earned half of the total value of all tenders (with the top 10% of companies collecting almost 80% of all tender revenue). About 70% of surveyed mining-related companies provide services for only one coal enterprise, indicating strong market connections and a strongly one-sided bargaining scenario. Understandably, remaining mining-related companies with a more diversified customer portfolio are less vulnerable to demand disruptions. In this group, 1% of companies delivered their products and services to all five coal mining enterprises (Figure 1). During the transformation process, they remain crucial for the region and the hard coal mining sector.

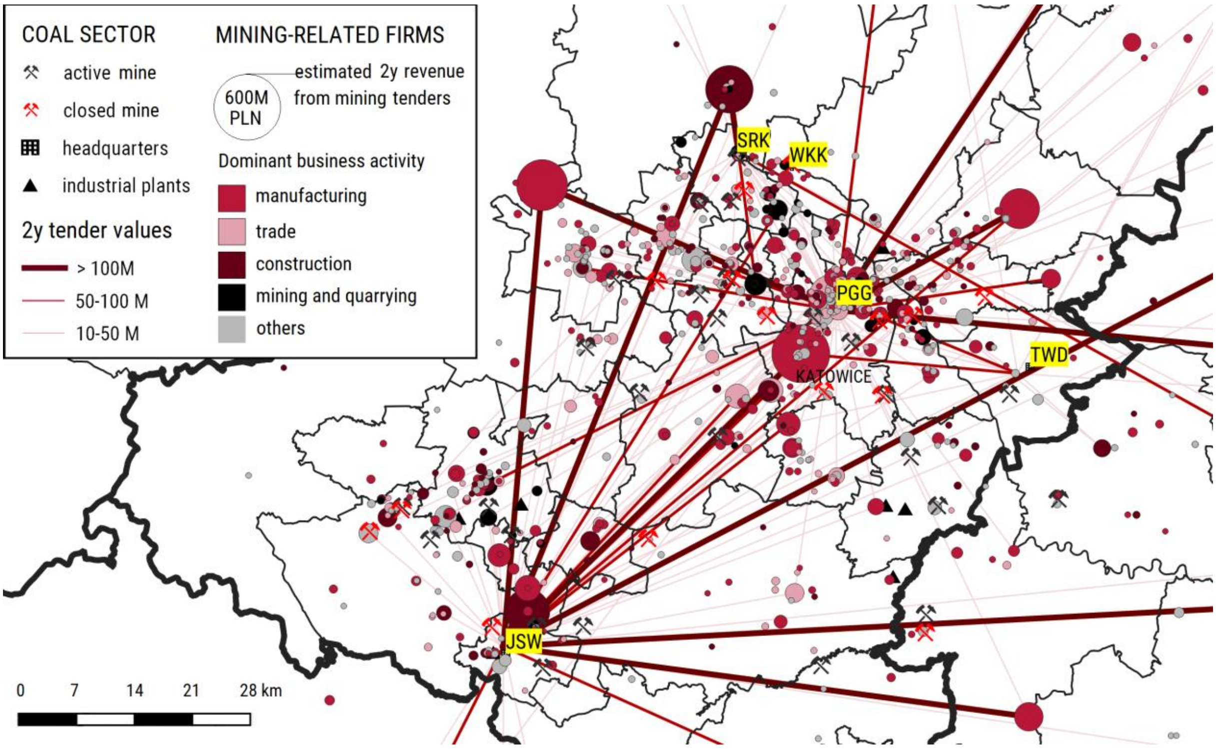
Figure 1. Network of mining-related companies



Note: This figure presents all mining-related companies, not only those from Upper Silesia. The NACE section was assigned according to the declared dominant business activity. SRK shared data on small mining-related companies on their public procurement portal.
Source: own elaboration based on data obtained from PGG/JSW/TWD or scrapped from company websites (SRK/WKK).

Assuming a bottom-up approach allows for indicating precise company locations. Such characteristics are crucial in estimating the regional and local impact of transition and planning policy interventions tailored to local labour markets. Most mining-related companies are located in Upper Silesia (70%, with the remaining 7% in an adjacent region of Lesser Poland). The companies in Upper Silesia obtained 80% of all tender revenues (with almost 20% going directly to companies based in the region's capital city – Katowice), indicating that the burden of an unmitigated coal phase-out may negatively affect the region's mining municipalities and their inhabitants. It should be noted that companies in the region and the capital city have already started altering industrial production. At the beginning of 2022, there was only one active coal mine in Katowice, and during the last two decades, the city transformed its economic base towards a more service-oriented profile. This shift, which is seeing further support from regional authorities, allows for the development of new industrial market chains and provides new opportunities for businesses to limit their dependence on mining.

Map 1. Location of mining-related companies by section and revenues



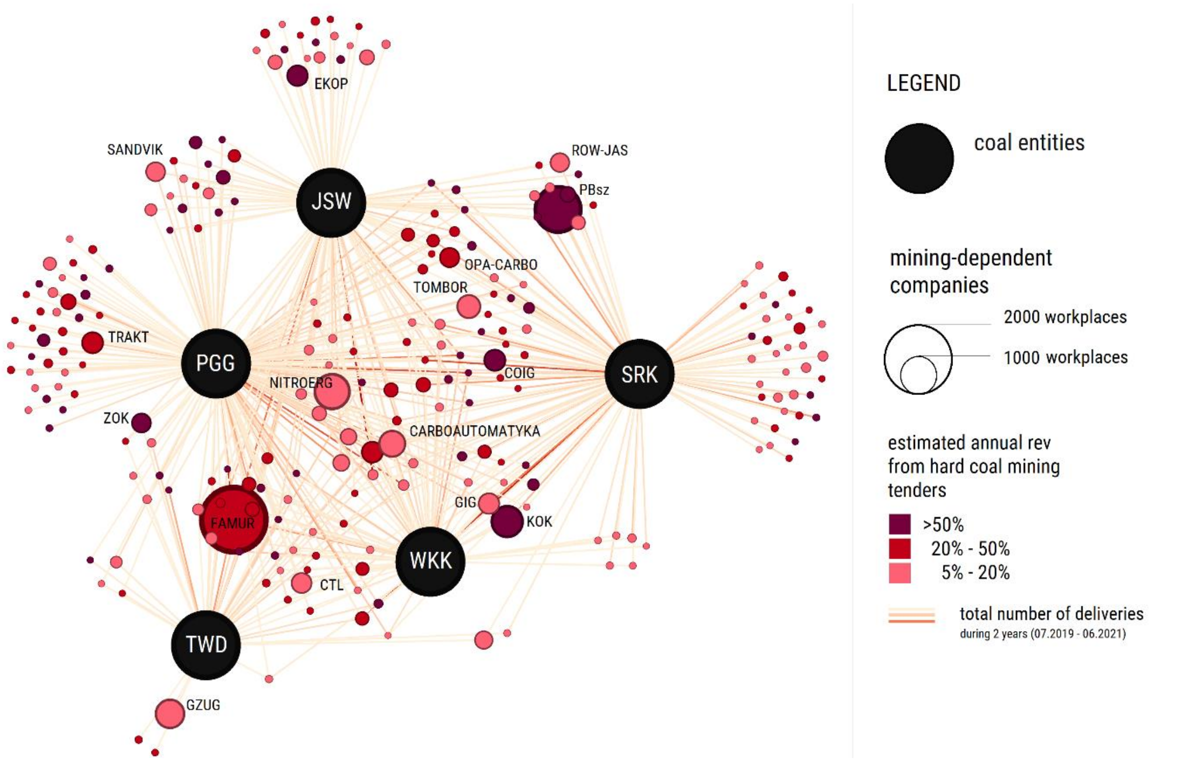
Source: own elaboration based on data obtained from mining companies.

3.1.2. Mining-dependent employment

So far, few studies have estimated the number of mining-related workplaces attributed to hard coal mining in Poland. Moreover, these studies differ in methodology and results. The estimated number of indirect workplaces in research reports and publications in the case of hard coal mining varies from 14,000 to 130,000 in Poland (→ Appendix 4). An official document signed between trade unions and the government indicated about 410,000 workplaces in this sector, spread across 73 mining communities and among mining-related companies. It should be noted that this number is inflated as it was only based on a single, simple assumption that one workplace in mining generates five additional workplaces in indirect and induced activities.

A bottom-up approach reveals the disproportions between companies in coal market chains. Mining-dependent companies are much smaller than coal mining companies in terms of employment (Figure 4). On average, 112 people work in a mining-dependent company (median: 33), while an average coal mine employs 2,852 people (median: 2,835). Only the largest mining-dependent company – Famur – hired a similar number of people (2,000) as one of the smaller Polish hard coal mines. Such discrepancy determines one-sided bargaining power in the transition. Employees of smaller and scattered companies have fewer opportunities to organise, mobilise and protect their interests. Therefore, they remain at the frontline of exposure to the negative economic consequences of coal mine closures. Identifying the most vulnerable companies is key for planning effective public policy interventions and safety nets.

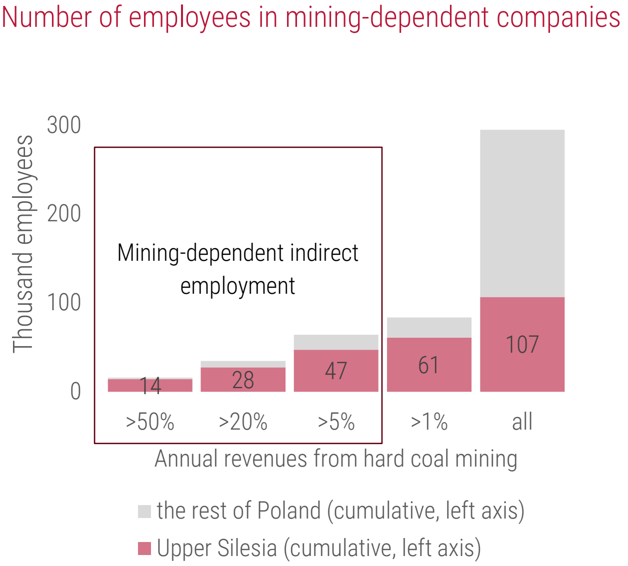
Figure 2. Network of mining-dependent companies in Upper Silesia

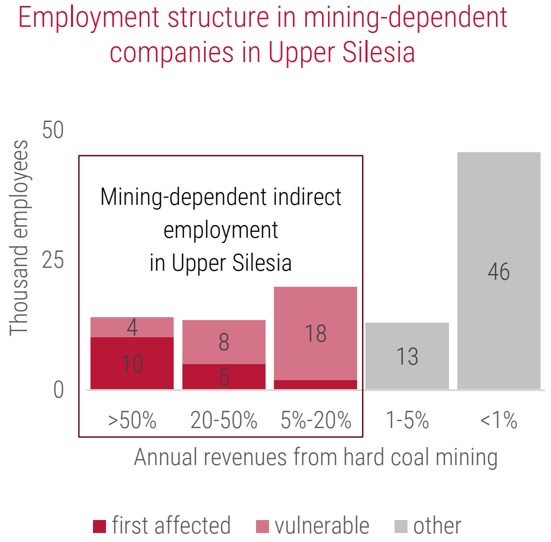


Note: This figure represents mining-dependent companies with headquarters in Upper Silesia with at least 5% of their annual revenues from hard coal mining tenders, which provided data about total employment (n=231).
Source: own elaboration based on administrative data.

Based on the bottom-up approach, we estimated that there are 51,200 mining-dependent workplaces in Upper Silesia (and 68,000 in Poland as a whole). The number of first-affected workplaces was 21,000 (41%), with the rest being classified as vulnerable (30,200; 59%). The largest group of indirectly affected workplaces was in companies that are relatively less dependent on mining (with revenues varying from 5–20%). The highest number of first-affected workplaces was in companies that generate most of their revenues from hard coal mining (Figure 3).

Figure 3. Number and structure of indirectly affected workplaces

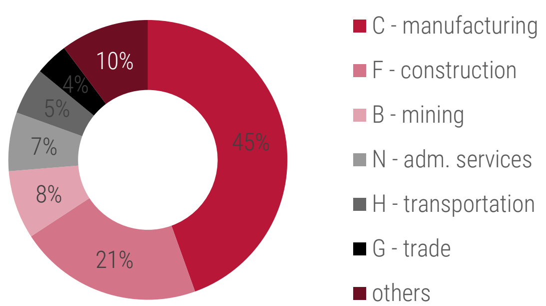


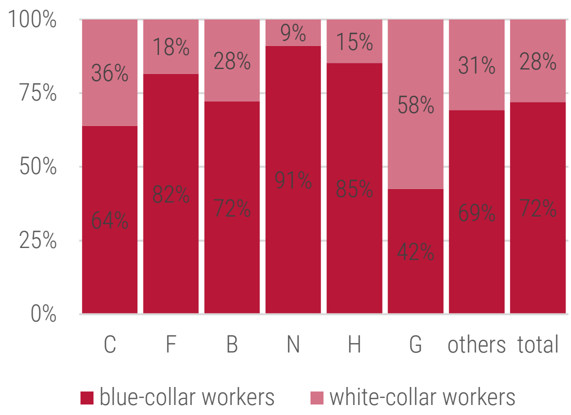


Note: The graph on the left presents employment in mining-related companies in Poland as a whole; the graph on the right presents employment in companies in Upper Silesia only.
Source: own elaboration based on administrative data.

Percentagewise, mining-dependent companies hire fewer blue-collar workers than coal mining enterprises. Almost 72% of mining-dependent company employees were blue-collar workers.[3] The largest share of blue-collar workers was identified in those firms that provide administrative, transportation, or construction services (Figure 5).

Figure 4. Employment structure in mining-dependent companies by NACE sections and dependence on coal mining contracts





Note: The chart on the left covers companies in Upper Silesia with at least 5% of their annual revenues from hard coal mining tenders which provided data about total employment (n=231); the chart on the right covers only all companies that provided information about employment structure (n=144)

[3] Percentage of blue-collar workers in mining is 77% (Frankowski et al., 2020b).

Source: own elaboration based on administrative data.

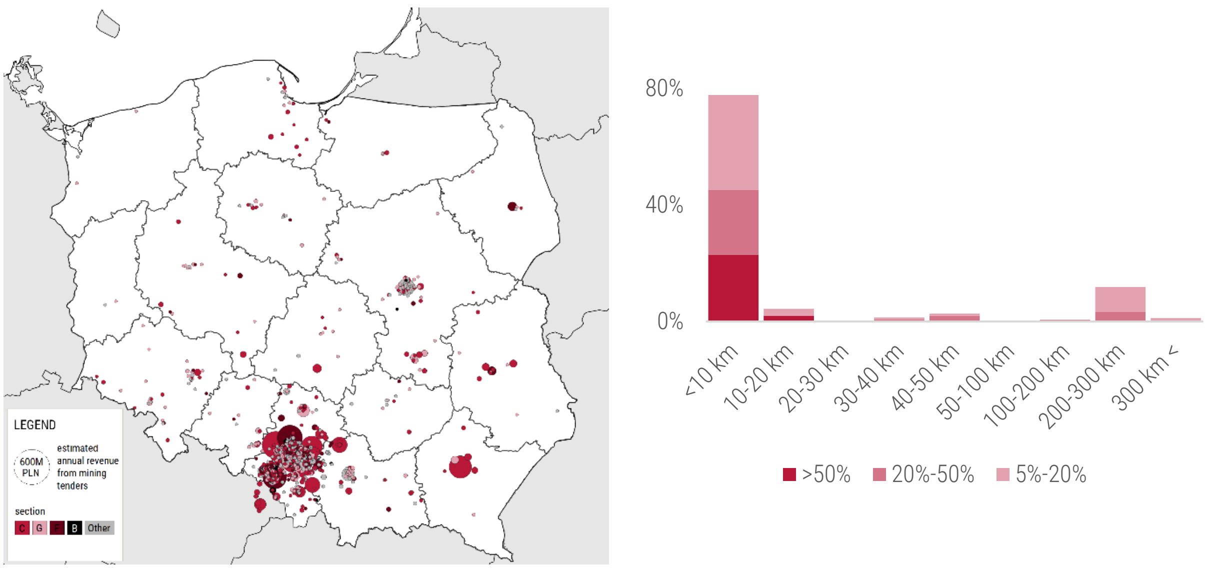
In manufacturing – the largest section of mining-dependent companies in terms of employment – the percentage of blue-collar workers was below average. Manufacturing and construction companies were more labour-intensive than trade companies. Considering the above, future coal mine closures will affect both white- and blue-collar workers, making it necessary to prepare both groups for the switch to other sectors and jobs.

3.2. Spatial interaction model

There is a noticeable agglomeration effect in the case of mining-dependent companies. 80% of all active hard coal mine tenders were awarded to companies less than 20 kilometres away.

Map 2. Distribution of mining-related companies in terms of distance to the nearest coal mine

identified mining-dependent companies | workplaces in mining-dependent companies



Note: financial data from WKK was unavailable.
Source: own elaboration based on data obtained from mining companies and administrative data.

Another advantage of our method compared to the I-O matrix approach is that it allows for the estimation of a spatial interaction model to forecast the effects of planned changes in spatial structure on interaction patterns. To conduct this exercise, we focused only on companies that reported data on their total revenues and employment. We first present the descriptive results (Table 1) that were input into our model described in equation (2). In this model, we disentangle the relationship between the estimated impact on a mining-related company with its distance to the closest active mine, a factor that is impossible to demonstrate using descriptive methods only.

Table 1. Descriptive results

Number of observations	464
Average estimated total revenue [PLN, millions]	16,87
Average number of first-affected employees	28
Median distance from closest active mine [in kilometres]	6

Source: own elaboration based on data obtained from mining companies and administrative data.

The distance between a mining-related company and its mining enterprise client is of minimal importance in terms of its exposure to the consequences of a mine closure (Table 2). First, most mining-related companies are clustered in Upper Silesia and located close to mining sites, which is reflected in the modelling results. Due to such clustering, spatial relation loses gravity and the inconsequential effect on the estimated impact of mining closure becomes negligible when the distance is exponentiated. Instead, we find the size of the company to be the most critical risk factor: the bigger the company, the higher its exposure to lost revenues and, therefore, layoffs.

Table 2. Mean marginal effects of the spatial interaction model described in equation (2) (standard errors in parenthesis)

variable	(1)	(2)
distance to mining site	-0.037 (0.022)	-0.043* (0.021)
$distance^2$	0.000 (0.000)	0.000 (0.000)
$distance^3$	0.000 (0.000)	0.000 (0.000)
$distance^4$	0.000 (0.000)	0.000 (0.000)
size of company	-	-1.132*** (0.155)
sector	-	0.016 (0.047)
number of clients	-	0.353* (0.157)
n	464	464

*Note: significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*
Source: own elaboration based on data obtained from mining companies and administrative data.

Applying our method (compared to the I-O approach) allows us to establish important policy implications. First, large mining-related companies – which are more reliant on mining sites – will be affected most severely by any mine closures and will therefore require targeted, assisted policy measures. Second, large mining-related companies (especially in the case of specialised manufacturing, e.g. mining machine producers) are less elastic to structural changes in the mining sector. Accordingly, switching subcontractor production to another specialisation will require additional capital investment in the case of a necessary coal mine closure. Finally, abusiness's distance to an active mining site is not the most important factor in their exposure. This shows that even in the closure of the closest mining site, subcontractors should be able to provide their services to other mines located further away.

4. Discussion

The measured bottom-up approach allowed us to assess the indirect employment effects of hard coal mining in Upper Silesia and the rest of Poland. We found it challenging to find a similar study and replicate this approach in other mining regions as predominantly privately-owned mining enterprises are not legally obliged to share their operational data. Hence, we confronted and embedded our results with indirect employment effects measured through different methodologies – in particular I-O modelling results.

First, discussing bottom-up measured indirect employment effects, we proved that decarbonisation could have an additional impact on 51,200 workplaces in coal mining areas in Upper Silesia. The indirect-to-direct job ratio calculated in this paper (1:0.71) remained higher than European Commission estimates (1:0.3 after (Alves Dias et al., 2018); 1:0.1 after (ESPON, 2020)) but lower than expert assumptions reported by industrial stakeholders and previous calculations based on input-output tables (1:1.16 – 1.35; Kiewra et al., 2019; Frankowski et al., 2020a → Appendix 3). However, these analyses covered the overall national effects of Upper Silesian mining and other plants, such as coal-fired heating and power stations (Frankowski et al., 2020a). The bottom-up approach resulted in a value between these estimations and enabled us to distinguish which businesses are vulnerable and likely to be affected first, and which workplaces may remain non-affected among mining-dependent companies. The adopted process shifted the discussion about indirect effects from the exact multiplier (indirect to direct job ratio) to the specific structure of affected industries and companies on a regional level. In this way, we overcame the limitations of I-O modelling.

Second, we identified a clear geographical clustering of indirect workplaces as the main challenge for the coal phase-out. We prove intra-regional linkages within the coal mining industry are stronger than interregional ones. It is in line with the general assumption that in terms of employment, a coal phase-out will affect small areas to a larger extent (Galgóczi, 2019). We confirmed that a noticeable agglomeration effect in the case of the mining-related sector also covered the Western part of a neighbouring region: Lesser Poland, which indicates the presence of vital economic connections between the two; a remnant of socialist administrative divisions and those from the country's early economic transformation period (1975–1999).

We realise that the case of Upper Silesia and mining-related companies may be exceptional compared to other coal regions, especially those outside of Europe. It is challenging to disentangle the current transitional processes from historical experiences of rapid mining closures in old industrial regions where coal is deeply rooted in regional tradition and culture (Della Bosca and Gillespie, 2018; Diluiso et al., 2021; Johnstone and Hielscher, 2017; Kuchler and Bridge, 2018; Leipprand and Flachsland, 2018; Heer et al., 2021; Sanz-Hernández, 2020). Entire supply chains, including many mining-related companies accounted for in our study, used to be part of larger state conglomerates. The socio-economic arguments to prevent business losses and avoid unemployment are vital within local communities and brandished by politicians against attempts to further the coal phase-out (Brauers and Oei, 2020; Ohlendorf et al., 2022). Consequently, mining-related companies constitute an integral piece of the existing mining ecosystem. Their attachment to decarbonisation reaches far beyond labour effects, even though many successfully transform their activities towards other sectors. In this regard, their transformative capacity should be the subject of further studies, as well as their economic (e.g. through taxes) and non-economic, qualitative contributions (e.g. through specific identity and cultural code).

5. Conclusions

In this paper, we estimated the scale, structure, and location of mining-related companies and their workplaces in Europe's largest coal mining region: Upper Silesia. Based on our novel bottom-up measurements, we carefully assessed that mining-dependent companies account for 51,200 jobs in the region, mostly in manufacturing and construction. We also identified a significant agglomeration effect of the hard coal mining industry. Undoubtedly, the presence of hard coal supply chains in the region will influence future coal phase-out planning and execution, requiring a complex policy framework for managing regional labour market consequences as the effects of a coal phase-out may also be burdensome on communes without active mines. Therefore, various forms of intervention for mining-dependent companies should be included and – considering the adopted time horizon – maintained in future regional development plans to mitigate the adverse economic and labour effects of downscaling coal production.

To maintain the resilience of the regional economy, it is essential to link mining-dependent companies with supply chains in industries that are likely to grow as a result of the energy transition process (e.g. construction, renewable energy) and high- and medium-tech industries (e.g. automation and robotics). Economic diversification requires planning support and allocating financial resources for larger, less flexible mining-dependent companies, as the spatial interaction model results suggest. Particular attention should be paid to workers. In terms of working conditions, mining-related workers are not protected like miners are, and they will be particularly exposed to mass layoffs. Although the administrative data helped better understand the proportion of blue- and white-collar mining-related workers, this group's exact age, gender, and structure remain unrecognised. Still, in the case of the most numerous groups of first-affected and vulnerable employees, an in-depth diagnosis of employment structure and working conditions should be the subject of further research.

Finally, we argue for the broader use of administrative data at the intersection of energy, labour, and regional studies. In this paper, we delivered a snapshot of the situation but have identified the necessity for data collection to be systemic and permanent for policy practice. An additional benefit of this would be that it would lead to more opportunities to conduct rigorous counterfactual studies on the direct and indirect impacts of coal mine closures on local municipalities in the future. We also call upon public sector services to open administrative data repositories and develop handy tools for data collection, extraction, and downloading to limit arduous, tedious and time-consuming work by researchers and practitioners. Such solutions would help keep track of trends with grounded bottom-up methodology studies to then compare with top-down, macroeconomic or econometric modelling, complementing strengths and breaking down weaknesses across all approaches.

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Appendix

A1. Basic information about hard coal mining state-owned enterprises

Enterprise	Full name	Share of assets owned by the state or state-owned enterprises	Employment (2020)	Number of active mines (2021)
PGG	Polska Grupa Górnicza S.A.	62%	39,559	13
JSW	Jastrzębska Spółka Węglowa S.A.	54.84%	22,302	5
TWD	Tauron Wydobycie S.A.	30.06%	6,458	3
WKK	Węglokoks Kraj sp. z o.o.	100%	2,311	1
SRK	Spółka Restrukturyzacji Kopalń S.A.	100%	2,847	---

Source: own elaboration based on administrative data.

A2. Indirect employment: data collection procedure

We relied on three sources of information to map mining-related companies – official reporting, data requests, and data scrapping. First, we collected data from official company reports. Second, we requested information from the largest mining enterprises on the tenders they offered between 1.07.2019 and 30.06.2021. We received this data from the three largest companies: Polska Grupa Górnicza (Polish Mining Group; PGG), Jastrzębska Spółka Węglowa (JSW), and Tauron Wydobycie (TWD). Third, we scrapped data found on tender portals run by Węglokoks Kraj (WKK) and Spółka Restrukturyzacji Kopalń (SRK). As a result, we drafted a list of all the mining-related firms that had won tenders from these five enterprises in the analysed period.

Next, we gathered company data about the legal structure, principal business activity, and address using various public administration databases (National Official Business Register, Ministry of Finance database, official company websites). For most companies with a National Court Register (KRS) number, we collected financial data on annual net revenues from sales and employment figures declared in the last available accounting reports.

We calculated the number of workplaces in associated companies (i.e. companies directly connected with coal mining enterprises) based on data from the last year that was available (Table 3). If a given associated company won a public tender, we classified it as a mining-related company. We excluded it from the group of associated companies (as they sometimes delivered services beyond parental entities).

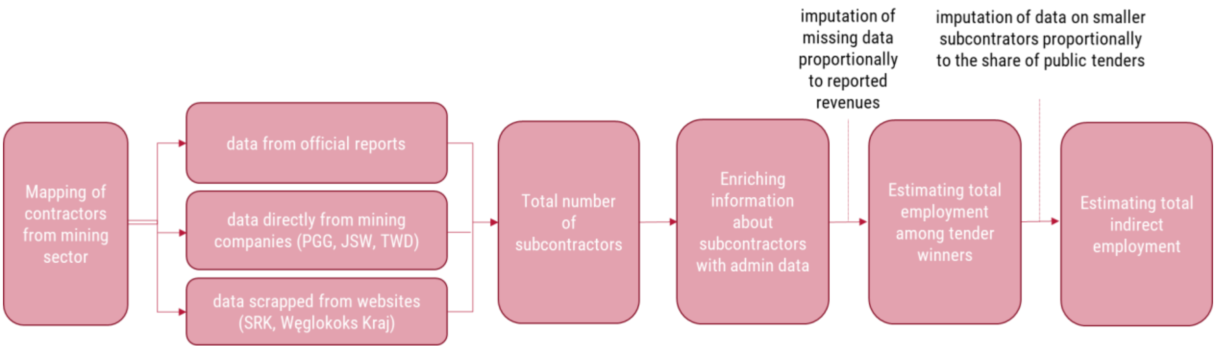
Table 3. Employment in companies associated with coal mining enterprises

Company	Companies classified as associated	Number of workplaces
PGG	Synercom Usługi Wspólne	3,684
JSW	Jastrzębska Spółka Kolejowa, JSW Logistics, JSW Szkolenie i Górnictwo, JSW Shipping[4]	
TWD	Spółka Usług Górniczych	
WKK	Węglokoks Kraj Serwis	

Source: own elaboration based on administrative data.

We supplemented the information about all the major mining-related companies (1,054) with employment data from KRS for coal mining enterprises in Upper Silesia. At the level of the whole dataset, total employment data was provided by 557 mining-related companies (53%), which covered 91% of the total mining tender value. The rest were mostly sole proprietorships – microenterprises in which the owner is responsible for the company. To provide complete employment data in the mining-related sector, we assumed that the missing number of employees would be proportional to the estimated revenues from tenders and the same in terms of dependence on mining. We added this parameter (7.42% for Upper Silesia) to the total estimation, excluding foreign companies from the sample.

Graph 1. The procedure of employment data collection



Source: own elaboration.

We imputed missing data about smaller mining-related companies. Due to business confidentiality, coal mining enterprises refused to share information about small mining-related companies[5]. However, in its annual report, PGG informed that 62% of its purchasing budget went through public tenders in 2020. So, we treated the rest as the contribution of smaller companies, assuming that:

- the share (38%) of the tender value of small mining-related companies in PGG is representative of the other coal mining enterprises;

[5] According to current legal regulations, the contract amount that obliges the contracting authority to conduct a tender for supplies and services was EUR 443,000 until 2019 and EUR 428,000 from 2020.

- the group of smaller companies is entirely different from major mining-related companies;
- the number of workplaces among smaller companies is proportional to the major mining-related companies' estimated revenues from tenders;
- small companies have the same dependence on coal mining as major mining-related companies.

To provide a final number of mining-dependent workplaces, we narrowed the number of employees attributed to the companies with annual revenues from mining higher than >5%. In doing so, we excluded large companies such as ING Bank Śląski or Orange Polska, which derived most of their revenues from non-mining clients and classified them as 'non-affected' (Table 4).

Table 4. Estimates of mining-related workplaces broken down by nationwide and regional impact

Mining-related workplaces	nationwide (Poland)			regional (Upper Silesia)		
	registry data	after CF_1	after CF_2	registry data	after CF_1	after CF_2
total (including non-affected)	169,454	183,038	295,222	61,385	66,306	106,945
only mining-dependent	36,891	39,848	64,272	27,255	29,439	47,483

Source: own calculations.

We distinguished two separate categories among mining-dependent workplaces: first-affected and vulnerable. We intended to provide an additional scenario of what should be considered a "mining-dependent" workplace in this group. We calculated the number of "first-affected" employees in a given company to be proportional to the precise share of revenues from the mining sector and classified the rest as "vulnerable". In doing so, it is indicative that this first group will be most prone to layoffs (Table 5).

Table 5. Estimates of mining-dependent workplaces broken down by nationwide and regional impact

Mining-dependent workplaces	Total (in Upper Silesia)	associated workplaces	mining-dependent workplaces (Upper Silesia)		mining-dependent workplaces (Poland)	
			first affected	vulnerable	first affected	vulnerable
Upper Silesia	51,167	3,684	17,273	30,210	19,487	44,785

Source: own calculations.

We added figures from associated and mining-dependent workplaces to obtain a total number of indirect workplaces. This gave us 51,167 indirect workplaces in Upper Silesia that are related to coal mining activity in the region.

A3. Measurement of indirect employment effects of the coal mining industry in Poland

Study	Authors	Year	Methodology and assumptions	Workplace estimations
Institute for Structural Research (IBS)	Frankowski et. al.	2022	Bottom-up measurement based on data on mining-related companies in public tenders from the five largest coal enterprises (2019 – 2021), enriched with financial and employment company data from administrative repositories. Mining-dependent companies are defined as firms with at least 5% of their estimated annual revenue	Poland: 67,956, first-affected: 23,171; vulnerable: 44,785 – mining-dependent companies (contractors) Upper Silesia: 51,167, first-affected: 20,957;

			coming from contracts with the five largest coal enterprises in Upper Silesia.	vulnerable: 30,210 – mining-dependent companies (contractors)
Joint Research Centre (JRC)	Alves Dias et.al.	2018	I-O (Eurostat)[6]. The estimation of indirect employment in the coal sector relied on input-output tables and multipliers originally developed by the EU Joint Research Centre for predicting the impacts of a change in final demand of one sector on other related industries (Mandras et al., 2019). Indirect employment was estimated by applying the same multipliers to the number of direct coal workplaces. Besides extending supply-chain coverage to all sectors that might be impacted by changes in coal mining and coal power plant activities, the indices used are assessed at an intra-regional level and consider spillover effects at an inter-regional level.	Poland: 48,746 (intra-regional), 87,760 (inter-regional) Upper Silesia: 22,106 (intra-regional), 34,536 (inter-regional)
Joint Research Centre (JRC)	Mandras and Salotti	2021	Rhomolo-IO model. The model contained disaggregated regional economic accounts based on I-O tables for 2013.	Upper Silesia: 7545 (intra-regional); 6363 (inter-regional)
Institute for Structural Research (IBS)	Kiewra, Szpor, Witajewski-Baltvilks	2019	Input-Output (Central Statistical Office, base year 2015) Indirect workplaces are calculated as the share of value-added transferred to the mining industry in the total value-added generated in a given section multiplied by the number of employees in this sector (according to data for 2017)	56,700 – suppliers 16,300 – recipients (coal-fired power plants)
	Frankowski, Mazurkiewicz	2020	Input-Output (Central Statistical Office; the base year 2015) Indirect workplaces are calculated as the share of value-added transferred to the mining industry in the total value-added generated in a given section multiplied by the number of employees in this sector (according to Eurostat data for 2018) + additions of employment in Section C (coking plants) and D (power and heating plants), proportionally to the share of coal in a given sector	96,000 – 112,000 contractors 41,000 – 56,700 intermediaries 55,300 (coal-fired power plants, heating and metallurgic plants)
The University of Economics in Katowice	Ingram et.al.	2020	Survey (207 companies; sampling frame not specified)	Total number of indirect workplaces: 110,000 – 130,000 Several affected indirect workplaces (until 2030): Optimistic scenario: 26,667; Plausible scenario: 50,580;

[6] The share of added value associated with mining to the mining added value is the same as the share of mining-related workplaces to the number of mining workplaces.

	Pessimistic scenario: 75,876

Source: own elaboration.

A4. Addressing limitations

A detailed methodology naturally entails providing elaborate strategies to overcome data limitations for further investigations or study replication.

Due to business confidentiality regulations, mining enterprises denied sharing information about their contractors. We managed to cover all major mining-related enterprises and conduct an imputation in smaller mining-related companies based on the share of non-public deliveries available in one of the mining company's annual reports (Measuring – formula (1) in Section 2.1.2).[7]

Second, we focused only on those mining-related companies that won tenders rather than all tender participants to ensure a coherent methodological approach. The database included information about companies that won at least one contract. We assigned the total contract value only to the consortium leader due to the lack of detailed data about the shares of each participant and, in some cases, other consortium members.

Third, we reported all missing data transparently. We could not collect financial and employment data from sole and civil law proprietorships as they are not obliged to report it. Some companies with KRS numbers did not provide any information about their revenues, total employment, or structure. Of the 100 biggest mining-related companies,[8] 95 companies provided information about full employment. For the missing data, we imputed total employment proportionally to their share of revenues on the aggregated level (Measuring – formula (1) in Section 2.1.2).

Fourth, we estimated the dependence of each mining-related company on the mining sector. We calculated the share of annual net revenues from mining based on tender data provided by the mining company and total annual revenues in the last reported year of a particular mining-related company. To be more accurate in our estimations, we analyse mining-related companies in five thresholds (e.g. 5 – 20% of annual revenues from mining) and use the exact measure of dependence on coal mining.

Fifth, we verified the data with official company websites and other reliable sources. We compared the list of mining-related companies with the members of the Polish Mining Chamber of Industry and Commerce (Górnicza Izba Przemysłowo-Handlowa). This leading mining-related business institution associates the most active mining-related companies. According to our data, 38 out of 46 industrial and service institutions won at least one tender during the analysed period, so we can state with a fair amount of confidence that our study covers the most active members of the industry.

[7] According to current legal regulations, the contract amount that obliges the contracting authority to conduct a tender for supplies and services was EUR 443,000 until 2019 and EUR 428,000 from 2020. According to the information obtained from the largest hard coal producer, PGG group, 62% of orders are carried out under the public tender procedure.

[8] Which covers 79% of the total value of all tender revenue.

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