Production Linkages and Regional Development: Evidence from Coal Mining in Germany*

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Word count: 2,300

Link to full paper

Abstract

This paper examines how production linkages shape regional adjustment to industry shocks. I study this question by comparing hard coal and lignite mining in Germany. Both coal industries operated under the same institutional and macroeconomic conditions but differed markedly in their integration into local supply chains. Using a novel county-level employment dataset for Germany spanning 1849–2024, I estimate an event-study and a shift–share design. I find that hard coal mining, which produces strong upstream and downstream linkages, led to persistent increases in local manufacturing and service employment, particularly in input-supplying and coal-using industries. In contrast, lignite mining, with weaker linkages, led to local industrial decline, consistent with Dutch disease dynamics. I further show that the phase-out of hard coal caused substantial employment losses, particularly in formerly linked sectors. These results highlight the double-edged nature of production linkages: they fuel growth while a key industry is active, but can amplify local decline once it contracts.

Keywords: Production Linkages; Local Multiplier; Resource Extraction; Structural Change; Deindustrialization

JEL Codes: J21, O14, Q32, Q33, R11

*I am deeply grateful to Erik Hornung and Michael Krause for their invaluable support and guidance throughout this project. I would also like to particularly thank Guy Michaels for hosting me during a research visit to the LSE and for his generous feedback and encouragement, which significantly enriched this work. I further thank Rainer Fremdling, Richard Franke, Sebastian Braun, and Felix Kersting for sharing data. I also thank Björn Brey, Alan Fernihough, Andrew Goodman-Bacon, Tobias Korn, Ola Olsson, Carola Stapper, Jörn-Steffen Pischke, Nikolaus Wolf, and the participants of the LSE Labour Economics Seminar 2024 (London, UK), the EHES 2025 (Hohenheim, Germany), the WEHC 2025 (Lund, Sweden), and seminar participants at Cologne for helpful comments and suggestions.

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1 Introduction

Industry shocks produce divergent local outcomes, generating positive employment spillovers in some regions while causing stagnation or decline in others. Understanding how industry shocks affect regional economies is increasingly important. In many advanced economies, rising regional inequality has fueled political discontent, weakened social cohesion, and increased interest in industrial and place-based policy.[1]

Natural resource extraction is a particularly salient example. It has long shaped regional development, from the coalfields of Europe to the oil towns of North America and the mining zones of Latin America and Sub-Saharan Africa. Yet its local effects are strikingly uneven. Some mining regions experience sustained industrial growth, while others face deindustrialization or persistent decline.[2] Despite extensive research, the mechanisms behind this divergence remain poorly understood. Why do some resource-rich regions thrive while others fall behind?

In this paper, I examine one potential mechanism behind the heterogeneous local effects of industry shocks: the strength of local production linkages. Production linkages refer to the extent to which activity in one sector stimulates economic activity in other sectors through input demand and output supply (Hirschman, 1958). Isolating the role of production linkages is empirically challenging, as structural and institutional differences across regions and industries typically confound causal inference. To overcome this, I exploit a natural experiment in Germany (1849–2024). I compare the local effects of extracting two types of coal, hard coal (or black coal) and lignite (or brown coal). Both were mined under similar national institutions and at comparable scales, but differed markedly in their integration with the local economy. Hard coal extraction requires complex underground mining techniques and generates strong upstream linkages through demand for machinery, engineering, and metalworking. Its high energy density also made it a key input in a wide range of industries, creating substantial downstream linkages.[3] In contrast, lignite is extracted

[1] For industry shocks and local adjustment, see e.g. Autor et al. (2016), Black et al. (2005), Feyrer et al. (2017), Greenstone et al. (2010), Hanson (2023), and Hooker and Knetter (2001). On the political and social consequences of regional divergence, see e.g. Autor et al. (2020), Dippel et al. (2022), Pierce and Schott (2020), and Rodríguez-Pose (2018).

[2] A large empirical literature has documented both negative and positive long-run effects of resource extraction on local economic development. For negative effects, see e.g. Esposito and Abramson (2021), Papyrakis and Raveh (2014), and Shao et al. (2020); for positive effects, see e.g. Aragón and Rud (2013), Cavalcanti et al. (2019), and Michaels (2011). For overviews, see Havranek et al. (2016) and van der Ploeg (2011).

[3] *Upstream linkages* refer to input relationships where local industries supply goods or services to the mining sector. *Downstream linkages* refer to industries that use mining outputs (here, hard coal or lignite) as inputs in their

through simpler surface mining. In addition, due to its lower energy content, it was largely used for electricity generation and local heating. As a result, lignite mining is much less integrated into surrounding industries. This setting enables a within-country comparison of two closely related industries. Both coal industries operated within the same legal, institutional, and macroeconomic environment but differed markedly in their degree of local economic integration. This provides a credible framework to isolate the role of production linkages in shaping local economies, both during periods of industrial expansion and in the aftermath of sectoral decline.

To derive testable predictions about how extractive industries shape regional labor markets, I develop a conceptual framework building on the local multiplier model of Moretti (2011). The framework predicts that sectors such as hard coal mining, which are embedded in local production networks, generate stronger spillovers to other tradable sectors and amplify demand for local services.[4] In contrast, sectors that operate as enclaves, such as lignite mining, are less likely to generate positive spillovers and may even crowd out other tradables by raising input costs.[5] Importantly, the very linkages that support growth during extraction may also increase exposure to decline. My framework implies that hard coal regions experience larger employment gains during the extraction period, but also sharp contractions during the coal phase-out. Lignite regions, by contrast, are likely to see few benefits, or even adverse effects, during extraction, but smaller losses during decline. I test these hypotheses empirically by analyzing the local effects of hard coal and lignite extraction in Germany during the coal extraction and phase-out period.

To examine whether differences in local linkage intensity shaped the long-term employment effects of resource extraction, I construct a novel county-level panel dataset for Germany from 1849 to 2024. I harmonize historical occupation titles from 28 censuses and align administrative boundaries, accounting for major political transitions from Prussia to modern-day Germany. My dataset spans more than 170 years and covers the rise, peak, and decline of both hard coal and lignite mining. To my knowledge, this is the first county-level dataset that captures local employment over such a long time span and industrial scope in Germany (Bartels et al., 2025; Berbée et al., 2025;

own production processes.

[4] This also echoes insights from staple theory, which emphasizes that the long-run impact of extracting a natural resource (the *staple*), depends on the extent to which it creates linkages to other sectors of the economy (Gunton, 2003; Watkins, 1963).

[5] Higher mining employment can raise local wages, increasing production costs for all firms. Since tradable goods are sold in national or international markets, local producers cannot pass these costs on to consumers and may become uncompetitive.

Peters, 2022). I link this dataset to historical input–output tables to classify manufacturing sectors by their upstream and downstream linkages to coal mining, enabling a disaggregated analysis of sectoral spillovers.[6]

To identify the local effects of coal extraction, I combine two complementary empirical strategies. First, I implement an event-study design that compares employment dynamics across hard coal, lignite, and non-coal regions in the years leading up to and following (i) the onset of large-scale extraction and (ii) the coal phase-out. To address concerns that mining activity may be endogenous to local conditions, I proxy for extraction using spatial variation in coal-bearing strata, which were formed long before modern economic activity and are plausibly exogenous (De Pleijt et al., 2020; Esposito & Abramson, 2021; Fernihough & O'Rourke, 2021).[7] Second, I estimate a shift–share specification that interacts annual variation in global coal prices with county-level exposure to coal deposits. This design exploits plausibly exogenous variation in exposure to global shocks to estimate the cyclical effects of extraction on local labor markets.

My findings show that the strength of local production linkages plays a central role in shaping the long-term effects of resource extraction. The event-study results show that the large-scale expansion of hard coal mining, characterized by strong local linkages, led to sustained gains in manufacturing employment. On average, manufacturing employment increased by approximately 19 percent relative to non-coal regions. These gains were driven by employment growth in linked industries, those supplying inputs to mining (upstream), those using coal as an input (downstream), and those with both types of linkages. Service employment also increased, consistent with local demand spillovers from rising income and population, while agricultural employment declined as regions industrialized. In contrast, lignite mining, marked by weaker local linkages, led to industrial decline. Manufacturing employment fell by approximately 20 percent alongside similar contractions in the service sector. These patterns suggest limited spillovers and crowding-out effects, consistent with Dutch disease dynamics (Corden & Neary, 1982; Krugman, 1987). Consistent with the sectoral responses, urban population increased in hard coal regions but not in lignite regions. This supports

[6] Upstream sectors include, for example, *Machinery* and *Wood products*, which supply equipment and materials to mining operations. Downstream sectors include *Primary metals* and *Nonmetallic mineral products*, which rely on coal as an energy input. Industries with weak linkages to coal include *Food and beverages*, *Apparel*, and *Printing and publishing*. The classification is based on the U.S. input–output table from 1947 (U.S. Bureau of Economic Analysis, 2019).

[7] I confirm that the distances from county centroids to hard coal and lignite fields are highly correlated with the distances from county centroids to carboniferous and lignite rock strata, respectively.

the interpretation that hard coal mining contributed to broader local development, whereas lignite mining did not.

I use the shift–share approach to complement the event-study findings by leveraging a distinct identification strategy that captures short-run responses to global coal price fluctuations. The results support the conclusion that coal booms raised labor demand in hard coal regions, but not in lignite areas. This reinforces the central role of production linkages in shaping the local effects of natural resource extraction.

After the phase-out of hard coal beginning in the 1960s, hard coal regions experienced pronounced deindustrialization. Manufacturing employment declined by about 21 percent relative to non-coal areas after 1961. A long-run event-study spanning 1849 to 2024 suggests that the employment gains in hard coal regions following the onset of large-scale extraction were largely offset by subsequent losses during the phase-out. The vulnerability of hard coal regions cannot be attributed to a lack of industrial diversification: hard coal regions became more diversified across manufacturing industries during the extraction period. Rather, my results point to the depth of integration with the coal economy as the key factor shaping the severity of employment losses following the decline of the hard coal industry. The decline of the lignite industry, which began in the late 1980s, also had negative effects, but these were substantially smaller.[8]

Taken together, my results suggest that regions with a strongly integrated key industry tend to gain more during periods of industrial activity but face sharper contractions when that industry declines. In contrast, regions where a major industry is weakly linked to other local sectors tend to experience adverse effects during its operation, but more limited losses during its decline.

Contribution to the literature. This paper makes important contributions to the literature. First, it contributes to research on regional adjustment to industry shocks by identifying local production linkages as a mechanism shaping the long-run effects of industrial expansion and decline. Prior work documents persistent local impacts of trade shocks, plant closures, and resource booms (Autor et al., 2016; A. W. Bartik et al., 2019; Black et al., 2005; Feyrer et al., 2017; Hanlon, 2017; Hooker & Knetter, 2001), but the channels through which these shocks propagate remain less well understood. By comparing two closely related industries within the same national setting that

[8] While lignite extraction in Germany has not yet been fully phased out, production has declined substantially since the late 1980s.

differ sharply in local supply-chain integration, I isolate the role of production linkages in shaping local economic outcomes. This is difficult to achieve in cross-country or single-industry studies, where institutional and structural differences typically confound identification. Using a newly constructed county-level employment panel covering 1849 to 2024, I show that strong production linkages amplify both the local gains from industrial expansion and the losses during sectoral decline. These findings also speak to the agglomeration literature by isolating the role of production linkages, distinct from other agglomeration channels such as knowledge spillovers, in shaping local economic development (Ellison et al., 2010; Glaeser, 2008; Marshall, 1890; Rosenthal & Strange, 2001).

Second, it extends the literature on local multipliers (Greenstone et al., 2010; Moretti, 2011). I demonstrate that both the size and direction of industrial spillovers to tradable and non-tradable sectors can vary substantially, even within a single industry, depending on the intensity of local production linkages. This also informs debates on place-based and industrial policy by identifying the types of sectors most likely to generate large local multipliers (Austin et al., 2018; T. J. Bartik, 1991; Criscuolo et al., 2019; Juhász et al., 2024; Kline & Moretti, 2014; Lane, 2025; Moretti & Thulin, 2013; Neumark & Simpson, 2015; Sheremirov & Spirovska, 2022; Siegloch et al., 2025). My results suggest that policies targeting sectors with strong local linkages are more likely to generate durable local gains. In contrast, support for enclave-type industries with limited economic integration may even crowd out other sectors and constrain broader development.

Third, it contributes to research on structural change and regional resilience (Acemoglu et al., 2012; Barrot & Sauvagnat, 2016; Carvalho, 2014; Gagliardi et al., 2023). I show that even relatively diversified regional economies can become highly vulnerable when their lead sectors are tightly embedded in local input–output structures. Contractions in a locally embedded lead sector propagate to upstream suppliers and downstream users through production networks. These network effects amplify employment losses and trigger broader industrial decline. This propagation dynamic also helps explain slow or incomplete adjustment to large shocks documented in recent work (Berbée et al., 2025; Dix-Carneiro & Kovak, 2017; Esposito & Abramson, 2021; Franck & Galor, 2021; Fritzsche & Wolf, 2023; Glaeser et al., 2015; Jacobsen & Parker, 2016). My findings highlight the importance of forward-looking transition strategies. These are especially important under planned shifts such as decarbonization, where coordinated policies may mitigate negative network spillovers (Dechezleprêtre & Sato, 2017; Walker, 2013).

Fourth, it adds to research on the local impacts of natural resource extraction (Allcott & Keniston, 2018; Aragón & Rud, 2013; Black et al., 2005; Lippert, 2014; Michaels, 2011; Pelzl & Poelhekke, 2021). I show that both the direction and magnitude of local effects depend on how deeply the extractive sector is integrated into the surrounding economy. This insight also informs the broader resource-curse debate (Cust & Poelhekke, 2015; Havranek et al., 2016; Sachs & Warner, 2001; van der Ploeg, 2011). My results show that variation in local linkage structures helps explain why resource extraction can lead to divergent long-run outcomes.[9]

[9] A related literature links resource booms to higher risks of violence and conflict, offering an additional channel for adverse local effects (Berman et al., 2017; Caselli & Michaels, 2013; Dal Bó & Dal Bó, 2011; Dube & Vargas, 2013).

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