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Demand (Un)certainty and Productivity: Evidence from the German Coal Mining Industry

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Competition, Management, and Productivity: Evidence from the German Coal Mining Industry*

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Abstract

We examine the role of management practices as an underlying mechanism to increase establishment-level productivity under reduced import competition due to an industrial policy in the German coal mining industry. The policy forced the downstream German steel sector to buy coal and coke exclusively from domestic coal mines, effectively reducing import competition and ensuring stable demand for coal mines with coking plants. We employ a difference-in-differences empirical strategy to track coal mines with heterogeneous shock exposure by exploiting exogenous variation in coal mines' suitability in coke production. We show that the policy increased quantity-based productivity (TFPQ) by around 6% and decreased marginal costs by 5%. Also, the vertically integrated cokerries improve TFPQ by around 20%. However, the anti-competitive effect of the industrial policy led coal mines to raise markups instead of completely passing on the efficiency gains to consumers. Using rich employer-employee-matched data on managers, we show that management practices to reduce demand uncertainty and promote mechanization were essential in explaining these efficiency gains under reduced import competition.

Keywords: Managers, Management Practices, Efficiency, Demand Uncertainty, Technology Adoption, Industrial Policy

JEL Codes: D24, L11, L52

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1 Introduction

Are firms that operate in more competitive markets more efficient? Whereas the positive relation between competition and productivity has been empirically identified in industrial organization (Olley and Pakes, 1996; Backus, 2020) and international economics (Pavcnik, 2002; Amiti and Konings, 2007; De Loecker et al., 2016; Brandt et al., 2017), among others, they usually abstract away the intermediary role of management practices by managers. In fact, while competitive pressure on firms can discipline managers and spur better practices (Bloom et al., 2016b), intense product market competition may also squeeze profits and manager pay (Bao et al., 2023), deterring top managerial talent. Hence, ambiguous net effects of competition on management practices could ultimately either increase or decrease productivity.

In this paper, we examine the role of management practices as an underlying mechanism facilitating firms' efficiency even in less competitive markets by exploiting an explicit industrial policy intervention in the German coal mining industry. We study a unique policy scheme forcing the downstream German steel sector to buy coal and coke, a product produced in coal refinement plants called cokeries, from domestic coal mines exclusively. This industrial policy effectively reduced import competition and ensured stable demand for coal mines with cokeries. We use employer-employee matched information on managers to track the changing manager hiring strategies of coal mines in response to the reduced import competition and investigate their effects on firm development.

We exploit exogenous variation in coal mines' suitability in coke production to capture their exposure to the policy shock. Note that coal mines with coking plants that synthesize coke from coal benefited from the policy straight. However, only half of the coal mines in the industry ran a cokery—mainly caused by the fact that, by nature, not all mines have the appropriate type of coal deposits in their coal fields for the use as coking coal. Therefore, we employ a difference-in-differences empirical strategy to track coal mines with heterogeneous shock exposure before and after the policy introduction. Coal mines with different magnitudes of policy exposure developed similar trends prior to the policy.

Several key features make the German coal mining industry an ideal laboratory for studying

the question at hand. First, a novel dataset that we digitized allows us to combine rich employer-employee-matched data on managers, production data, and characteristics for all mines and cokeries at the very granular establishment level. Second, coal is relatively homogenous within the same product category, while the corresponding quality difference is determined exogenously by nature. This helps to largely eliminate confounding factors related to product quality. Third, we observe both physical input and output information for coal mines at the establishment level, which allows us to estimate quantity-based total factor productivity (TFPQ) (Foster et al., 2008). Using TFPQ can ensure we distinguish the true efficiency impacts of import competition from market power, buyer power, and product quality. This differs from relying on revenue-based measures, as in most studies on import competition (Amiti and Konings, 2007; Topalova and Khandelwal, 2011; Bloom et al., 2016a; Brandt et al., 2017; Chen and Steinwender, 2021). Lastly, while we focus on one specific industry, the coal industry made up a sizeable part of the German economy for decades with 400,000 employees directly employed in coal mines in the early 1960s.

To obtain the true efficiency measure, we further allow endogenous productivity processes to consider explicit impacts of industrial policy exposures, new manager hiring, demand uncertainty, and beyond. Our difference-in-differences estimations show that the industrial policy triggered a positive and persistent surge in efficiency for coal mines with higher policy exposure. The TFPQ increased by around 6% in response to the policy intervention depending on different exposure specifications, where formerly less productive coal mines improved the most, ultimately leading to a significant increase in their survival probability.

In contrast, we find that marginal costs fell by 5% due to the policy and were primarily derived from the efficiency gains. However, coal mines raised their markups by 15% rather than completely passing on the efficiency gains to consumers. The increased markups were mainly driven by the industrial policy's anti-competitive effect, which indeed reduced import competition. The finding of the negative association between competition and productivity contrasts with the frequently identified empirical correlation that competition is productivity-enhancing.

Using the rich employer-employee-matched data on managers, we show that management practices are the primary mechanism of the increased productivity derived from the reduced import competition - i.e., managing practices matter (Bertrand and Schoar, 2003). We find that treated mines hired more new managers with STEM backgrounds, high own productivity, and experience at more productive former employers. These managers are likely to possess greater knowledge of coal mining technology and contribute advanced organizational practices to the mining operations. At the same time, coal mines suffering from high demand uncertainty tend to hire more new managers. The manager changes are essential in explaining the increased productivity and markups.

Finally, we illustrate that managers realize these efficiency gains for coal mines under reduced import competition by reducing demand uncertainty and promoting the adoption of mechanized production. We find that managers can not only manage coal mines but also utilize their expertise in managing affiliated coking plants and increase their efficiency significantly. In sum, the negative net effect of competition on productivity via management practices in our paper suggests that the channel—high market power leading to better managerial practices and talents dominates the overall impacts, which complements the other mechanism that competition may improve practices through increased pressure to perform.

Related Literature. Our paper contributes to a large strand of literature. First, we bridge the literature on management and competition on the one hand (Schmidt, 1997; Raith, 2003; Bloom et al., 2015; Antón et al., 2023; Bao et al., 2023), and management and productivity on the other (Bloom and Van Reenen, 2007, 2010; Bloom et al., 2016b, 2020; Fenizia, 2022; Demirer and Karaduman, 2024). The ambiguous total effects of competition on managerial incentives could lead to either an increase or decrease in efficiency; hence, it also connects with the broad empirical literature on the correlation between competition and productivity (Olley and Pakes, 1996; Pavcnik, 2002; De Loecker, 2011; De Loecker et al., 2016; Brandt et al., 2017; Backus, 2020).

The most related paper to ours is Chen and Steinwender (2021), which finds that import competition increases productivity in family-managed firms. We examine the role of manage-

ment practices in facilitating productivity in less competitive markets, showing that reduced import competition can also induce efficiency gain via various managerial activities. Our findings complement pervasive empirical observations that firms operating in more competitive markets tend to be more productive.

Second, we add to the literature on import competition and its consequences ([Grossman, 1982](#); [MacDonald, 1994](#); [Amiti and Konings, 2007](#); [Amiti and Khandelwal, 2013](#); [Autor et al., 2013](#); [Bloom et al., 2016a](#); [Traiberman, 2019](#); [Autor et al., 2020](#); [Amiti and Heise, 2024](#)). These studies find ambiguous impacts of import competition for heterogeneous firms in different country contexts ([Shu and Steinwender, 2019](#); [Liu et al., 2021](#)). Our paper differentiates from the literature by constructing the mine-specific within-industry exposure to the import competition by exploiting an industrial policy intervention rather than using import-related measures. We also utilize physical quantities of both input and output to estimate quantity-based productivity for coal mines, contrasting with revenue-based productivity in most import competition literature. This helps identify the true productivity effects of import competition from market power, buyer power, and product quality.¹

Our work also speaks to a growing literature on the role of different types of uncertainty on firm-level decision-making and industry-level reallocation, e.g., price uncertainty ([Kellogg, 2014](#)), macroeconomic fluctuations ([Bloom et al., 2007](#); [Bloom, 2009](#); [Bloom et al., 2018](#); [Jiang and Zhang, 2024](#); [Baker et al., 2024](#)), and policy uncertainty ([Baker et al., 2016](#); [Gowrisankaran et al., 2024](#)). We explicitly look at demand uncertainty, a far less studied dimension, using a novel and granular measure of demand uncertainty at the establishment level, i.e., the canceled shifts due to insufficient demand. [Collard-Wexler \(2013\)](#) finds that reducing demand fluctuations in the ready-mix concrete industry increases the market size and the share of large plants. [Guiso and Parigi \(1999\)](#) and [Kumar and Zhang \(2019\)](#) show that demand uncertainty reduces investments. Our paper contributes to understanding the interaction between demand uncertainty and management practices.

¹Arguably, this literature strand belongs to a larger group of work on the more general question of the linkage of competition and technology adoption as well as innovation, which so far found arguments both positive and negative signs on this relationship (e.g., [Aghion et al., 2005](#); [Schmutzler, 2013](#); [Shu and Steinwender, 2019](#)); also in non-trade policy contexts such as mergers and acquisitions as competition changes ([Bena and Li, 2014](#); [Guadalupe et al., 2012](#); [Haucap et al., 2019](#)).

Finally, our paper is also closely related to a broad literature on industrial policies (beyond trade policy) and their corresponding impacts. Former work has especially studied place-based policies (Becker et al., 2010; Ehrlich and Seidel, 2018; Hebllich et al., 2022; Kline and Moretti, 2014; Siegloch et al., 2025) and subsidy-heavy policies (Barwick et al., 2025; Criscuolo et al., 2019; Siegloch et al., 2025) or focussed on infant industries instead of industries under pressure and in decline (Barwick et al., 2024; Juhász, 2018; Lane, 2022). We look at a novel industrial policy with different policy designs and targets, namely reducing demand uncertainty through trade policy. Also, the mechanisms behind industrial policy have often been unclear so far and the transferability of industrial policy effects beyond the studied case studies has been unclear (Juhász et al., 2023). However, we identify a channel potentially relevant in most industries, i.e., manager reallocation and changing managerial practices.

The remainder of the paper is structured as follows. Section 2 presents the industry and policy background of the German coal mining industry and related datasets we used in the empirical analysis. In Section 3, we introduce the empirical strategy of the paper. In Section 4, we document the policy effects of the industrial policy before we analyze management practices as the underlying mechanism in Sections 5 and 6. Section 7 reports further robustness checks. Finally, Section 8 concludes.

2 German Coal Mining Industry and Data

This paper studies the German coal mining industry and its vertical relations to the downstream coke and steel production in the mid-1950s to 1980.

2.1 Industry and Policy Background

Coal Mining Industry and Coke Production in Germany. The German coal mining industry employed up to 500,000 workers in Western Germany at its peak in the late 1950s. It was the most significant operating Western European national coal industry at the time, serving as the primary supplier of energy for heating, transportation, power generation, and,

most importantly, coke production. Coke is a main ingredient in steel production, produced by cokerries using coal as main input. Panel A of Figure 1 shows the distribution of coal consumption by groups of purposes. Up to 40% of the produced coal is used for coke production. About half of all coal mines had a cokery vertically integrated and about 80% of all coke produced in Germany came from German coal mines' cokerries in 1969 (Gatzka, 1990). Figure 2 shows the industry value chain. Coal mines and cokerries are vertically integrated. However, not all mines have a cokery. Coal mines can use quarried coal to sell it directly or use it in cokerries to produce coke for the steel sector, if the type of coal is appropriate for coke production.

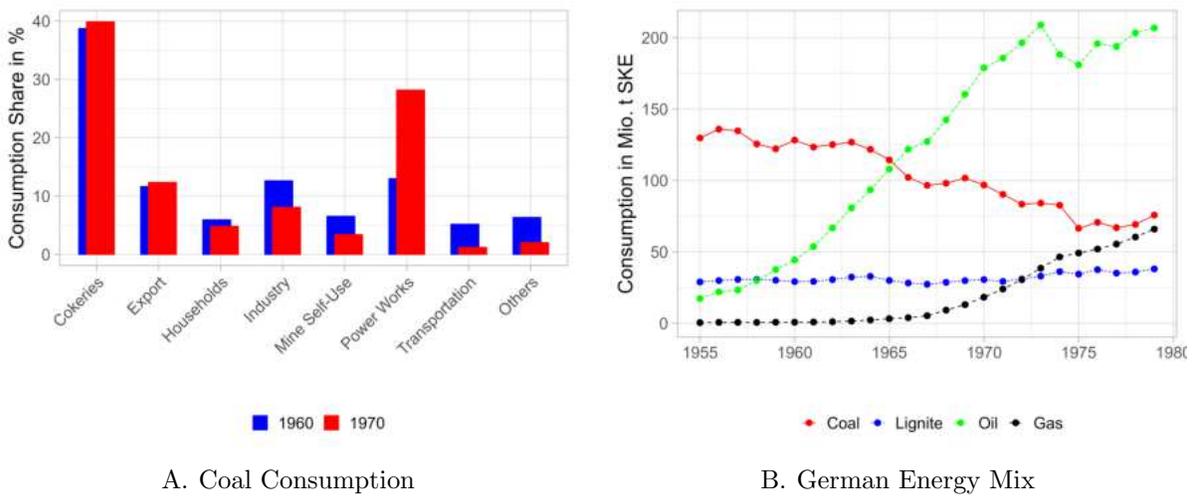


Figure 1: Coal Usage and the Rise of Oil

Notes: This figure gives the share of different purposes of coal consumption and the energy mix in Germany over time. Data comes from the Statistics Sections in the *Yearbooks of the German Mining Industry*.

German coal production faced increasing import competition threats from the late 1950s onwards. Better diplomacy with Near East countries and lower transportation costs improved the availability and affordability of oil as a prominent energy substitute for coal (Fritzsche and Wolf, 2023; Fischer, 2024).² Rising oil imports crowded out coal consumption throughout the 1960s in Germany, as seen in Panel B of Figure 1. Importantly, oil was only a substitute to non-coking coal given that the cokery process requires the refinement of coal, and, coke could not be replaced in the steel production process.

²Import coal, however, did not crowd out German coal as Germany had import contingents and tariffs on import coal (including coking coal) since the late 1950s (Fischer, 2024).

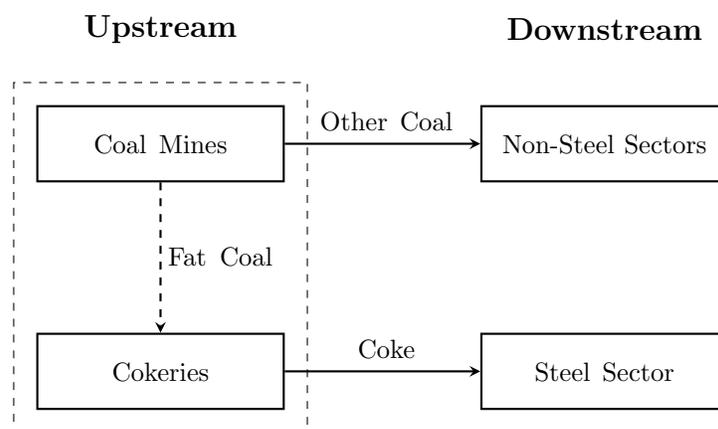


Figure 2: Industry Value Chain

Consequently, the German coal mining industry shrank substantially from 1960 to 1970 by 25% in terms of output. Employment and the number of mines halved over the same period. To smooth out the structural change process and avoid even more mass layoffs, the government conducted a series of industrial policies in the late 1960s and 1970s in the coal mining industry, with its central policy being the *Hüttenvertrag*.

Hüttenvertrag: A Substantial Decrease in Competition. Panel A of Figure 3 shows that import coking coal, i.e., coal suitable for the cokery process, has been cheaper than German coking coal throughout the late 1960s and 1970s. Lower import coal and coke prices led steel firms to consider substituting domestic inputs with foreign inputs; something which they had not considered before. Coke imports were only about 1% of the overall coke consumption in Germany in the 1960s (see Panel C) and coking coal import was capped through the import coal contingent named above (Storchmann, 2005). Hence, cheap import coke was a new threat to the German coal industry. Anticipating the risk and to sustain and smooth demand for the German coal industry (Gatzka, 1990), the government initiated an agreement, called *Hüttenvertrag* (Zydek, 1973), between the German coal mining industry and the downstream steel industry in 1969.

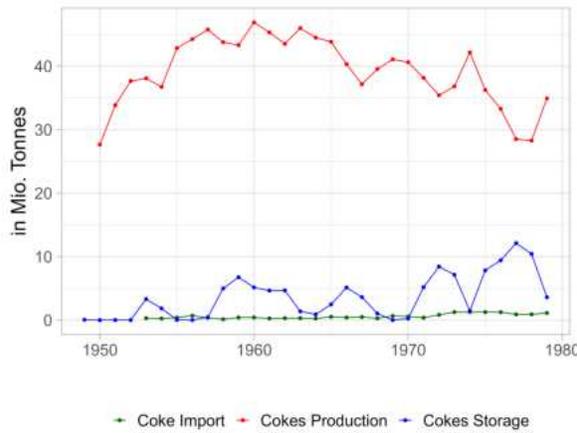
This agreement ensured that the German steel industry should use German inputs, which obligated it to buy all its coal and coke inputs for steel production from German coal mines. Price differentials between German coal and coke prices and the world market were almost fully compensated by the government. Until 1978, the difference was even completely compensated



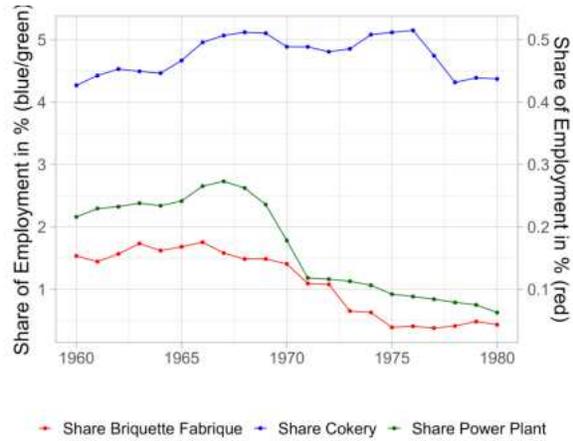
A. coking coal Prices



B. Coal Sales to Steel Industry



C. Pithead Stocks In-Storage



D. Employment by Refinement

Figure 3: Coal and Coke Situation and Cokery Employment

Notes: This figure gives the prices for German and foreign coking coal over time, the amount of German coal used in the German and European coal industry, and the share of employment by refinement type over time. Data for Panel A and B comes from [Gatzka \(1990\)](#). Data for panel C comes from the *Yearbooks of the German Mining Industry*.

given the small price difference between the German and world market coke price (Engels et al., 1988; Neu, 1995). The steel industry, in return, was prioritized in supply, i.e., for example households would be supplied after the steel industry. All mines owned by the *Ruhrkohle AG*, a quasi-monopolist in the German coal mining industry with about 85% market share, were part of the agreement. This policy led to imports being close to zero also in the 1970s even though prices diverged.

Contract Details. The contract was meant to “permanently secure sales” for German coal mines (see preamble of the contract and Gatzka (1990)) and was initiated by German politics in response to searching for a policy that “stabilizes sales at a certain level” (German Bundestag, 1967). This was achieved by (i) making it mandatory for German steelworks to purchase coal and coke from German mines (§2 of the contract), (ii) setting a contract length of 20 years (preamble of the contract),³ and (iii) making it obligatory for German steelworks to report their one-year and five-year forecasts of coal and coke demand (§4.1).⁴

German steelworks experienced a boom around the timing of the policy and in the early 1970s (Harders, 1970) and were very competitive in the world market during the 1970s (Aylen, 1982). This made a high level of coke demand for several years credible. Panel B of Figure 3 shows that the demand for coal and coke from the German steel industry remained relatively stable after 1969 while demand for German coal and coke from foreign, European customers shrank strongly. Panel D further makes clear that the number of workers employed in cokeries as a share of overall employment in the coal mining industries remained stable over the 1960s and 1970s. In contrast, employment in other types of coal refinery plants such as briquette plants and electricity plants declined.

As steelworks had to purchase coal from German coal mines in any case, the government set up several mechanisms to ensure that coal mines did not exploit the inelastic demand by setting high prices or by producing excess coal for storage. First, coal mines had to sell coal and coke to list prices (§6.1 and §7.1), which they also used for other non-steel consumers and

³One-sided cancellation is only possible after 15 years.

⁴Further, arbitrage by coal mines, i.e., buying coal and coke on the world market price and selling it to steel firms instead of own production, was not permitted (§1.5).

prices charged to non-German customers had to be at least as high as to German customers (§8.1). Second, the government could request cost data from coal mines to ensure that mines requested fair prices (Gatzka, 1990). Third, the annual price negotiations were meant to be close to coke prices from non-coal mine cokeries, i.e., independent cokeries (Attachment 2 to the contract). Lastly, an arbitral court could be applied (§14.2). In case of unfair practices by the coal mines, the government could increase the import-coal contingent (Gatzka, 1990). Panel C of Figure 3 shows that, indeed, the excess production of coke, that was stored on pithead stocks, amounted only to a few million tonnes relative to annual coke production of more than 30 million tonnes of coke. Hence, excess production for storage given the non-downward sloping demand was effectively prevented by the policy’s design.

For the steel industry, the policy therefore did not come at effective prices higher than the world market price. Further, the contract ensured that German coal mines could only reduce coke production below the agreed volume with the permission of the steel industry (§1.4). This allowed steel firms to save efforts in renegotiating contracts with suppliers as they had done before.

Overall, the policy led to government payments, which compensated the price difference between German and world market coal and coke of 8 billion DM (24 billion Euro in 2022 terms).

2.2 Data

We digitized annual mine-level production data published in the *Establishment Statistics of Statistik der Kohlenwirtschaft e.V.* and in the *Yearbooks of the German Mining Industry* from 1960 to 1980. We restrict our sample to mines that were owned by firms that signed the *Hüttenvertrag*. The few excluded mines were mainly not located in the Ruhr area, Germany’s primary coal district, but in the smaller and distant Ibbenbüren, Aachen, and Saar coal districts. These mines also did not operate cokeries. We further drop observations of mines that had partial closures through the *Rationalisierungsverband des deutschen Steinkohlenbergbaus*, a closure policy in 1963, to avoid our results taking up, for example, these output reductions.

This leaves us with 87 out of 101 mines that operated at some point during our sample period in Germany. The sample corresponds to around 80% of the overall German coal production during the sample period. We also exclude observations of mines in their closure year as, for example, employment data is usually collected at the end of the calendar year. In the end, our final datasets encompasses 975 mine-year observations.

Figure 4 shows a map of all coal mines in our sample by cokery status, which are all located in the federal state of Northrhine-Westphalia in Western Germany.

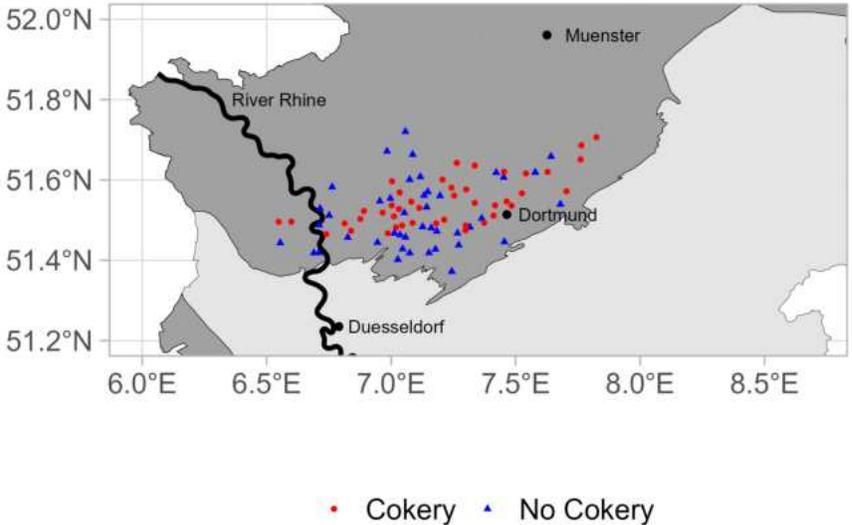


Figure 4: Geographical Location of All Mines

Notes: This figure gives the location of all mines in the sample by cokery status. The dark gray area gives the regions, in which coal deposits up to a depth of 2,000 metres can be found. Geolocation of cities (Duesseldorf, Dortmund and Muenster) plotted. The administrative borders are those of the German federal state Northrhine-Westphalia. Shapefile on NRW borders come from ([Information und Technik Nordrhein-Westfalen, 2023](#)). Shapefile on coal deposits come from ([Geologischer Dienst Nordrhein-Westfalen, 2023](#)). Shapefile on river Rhine comes from ([Generaldivision Wasserstraßen und Schifffahrt, 2021](#)).

We observe a wide range of mine-level information. First, the dataset includes unique physical input and output data, which allows us to estimate physical total factor productivity at the mine level using the production function approach, and track changes in the production process in response to the policy. We observe output in tonnes of coal, employment in the number of miner shifts, capital in machine power (in kW), and pit wood consumption in cubic metres. Input prices such as wages are also available.

Second, we observe which mines have an attached cokery. For such cokerries, we further

observe input and output information such as the amount of coal used as input, employment, and output in tonnes of coke. Also, the data comes with capacity information about cokeries, i.e., number of ovens and capacity in tonnes.

Third, the dataset reports unique information regarding the annual canceled miner shifts due to insufficient demand for each mine, which we use to proxy demand uncertainty. A larger difference between actual labor demand and hired labor reflects uncertainty in the production volume. While excess shifts only reflects a one-sided deviation of actual from expected input demand, this is the deviation mattering to firms. Too few employment could easily be countered by hiring new workers in a declining industry with excess labour supply.

Further, we gather annual lists of mine and cokery managers for all establishments and years from the *Yearbooks of the German Mining Industry*. This employer-employee matched data on managers includes information on, for example, the managers' names, so that we can track managers and their switching behavior across establishments, and their scientific education (i.e., field and degree).

Beyond that, there are additional mine-year data on other outcomes, such as technology adoption, the type of coal quarried in a mine, worker flows between mines, coal field size, number of vertical tunnels, and water management. Finally, we collect price data for the different types of coal and coke by year from the *Statistical Yearbooks of Germany*. Prices for specific types of coal do not vary at the mine level as they are centrally fixed through a joint retail organization of the coal firms.

3 Empirical Strategy

3.1 Empirical Specification

We study the policy effects by comparing various activities of non-cokery mines with cokery mines before and after the policy introduction. Specifically, we estimate the consequences of

the policy change using the following difference-in-differences specifications of the form:

$$Y_{it} = \beta Exposure_i \times Post_t + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (1)$$

where Y_{it} is the outcome variable for coal mine i in year t . $Exposure_i$ is a measure of exposure magnitude to the policy for each coal mine, and $Post_t$ is an indicator that equals one after 1969. α_i and λ_t refer to mine- and year-fixed effects, respectively. We cluster standard errors at the coal mine level to account for arbitrary serial correlations for the same mine over time. The coefficient β is the primary parameter of interest that represents differences in the outcome variable among mines with different exposure magnitudes to the policy.

As the policy targeted coke production, mines with higher exposure to coke should be treated more strongly. Specifically, we construct three different specifications for $Exposure_i$ to capture the exposure of a mine to the policy shock. First, we calculate the share of quarried coal that is used in the coke production ($[\%coking\ coal]_i$). We use the weighted average over pre-policy years to account for long-run exposure. Using only pre-policy years takes into account that post-policy values might already be subject to strategic responses (self-selection into exposure). Second, we employ a binary treatment based on whether a mine has a cokery attached or not in the pre-policy window ($\mathbf{1}[Attached\ Cokery]_i$). Third, we use the share of employees working in the attached cokery relative to the overall employment of the mine in the pre-policy window ($[\%Cokery\ Employment]_i$). These three measures capture similar but not identical ways of exposure to the policy. $[\%coking\ coal]_i$ accounts for the intensive margin of coke production while $\mathbf{1}[Attached\ Cokery]_i$ for the extensive margin. $[\%Cokery\ Employment]_i$ considers the relative importance of the side plant cokery for the overall mine. Table 1 summarizes all three exposure measures and their variation. Exactly half of all mines have a cokery attached. The maximum share of produced coal going into coke production is 83.5%. Mines employ up to 10% of their overall workforce in the cokery. We winsorize the two continuous exposure measures at the 95th percentile to avoid distant outliers to largely drive our results.

Selection Into Treatment. Whether a mine runs a cokery or not is not random. To under-

Table 1: Exposure Measures

	N	$\mathbb{1}[> 0]$	Min	p25	Mean	p75	Max
$[\%coking\ coal]_i$	87	44	0	0	0.255	0.514	0.835
$\mathbb{1}[\text{Attached Cokery}]_i$	87	44	0	0	0.506	1	1
$[\%Cokery\ Employment]_i$	87	44	0	0	0.033	0.064	0.100

stand what drives the adoption of coke production and whether there is potential to self-select into the policy, we run a simple multi-variate regression of the exposure variables on a number of variables that characterize the production technology. We only use pre-policy data to avoid distorting these variables with the treatment. Figure 5 shows that mines of low and high cokery exposure do not differ in important dimensions (e.g., TFPQ, size, technology) except for one dimension, i.e., the availability of fat coal deposits. This is pretty intuitive as fat coal is the type of coal used specifically in cokery production, which rationalizes why only these mines adopt cokeries. Importantly, it is predetermined by nature whether coal mines find fat coal in their coal fields or not. Hence, there are no observable differences between mines with different cokery exposure levels. That is important as it underlines that the cokery mines do not strongly differ and serve as a suitable control group.

Dynamic Effects. To provide evidence that mines with different exposure magnitudes had similar trends before the introduction of the policy, we also implement event studies for our baseline difference-in-differences analyses by replacing the $Post_t$ indicator with a series of year dummies:

$$Y_{it} = \sum_{\tau=1960, \neq 1969}^{1980} \beta_{\tau} \times Exposure_i \times Year_{\tau} + \alpha_i + \lambda_t + \varepsilon_{it}. \quad (2)$$

The coefficients β_{τ} capture differences in the outcome variable among mines with different exposure magnitudes to the policy in year τ . We plot the estimates of β_{τ} 's to exhibit the evolution of corresponding dependent variables relative to policy introduction across time. In all related figures, we rescale the y-axis to make the effect size of all three exposure analyses comparable. To do so, we multiply the estimated coefficients of each regression with the mean of the exposure variable of with strictly positive exposure. This means, we weight the coefficients

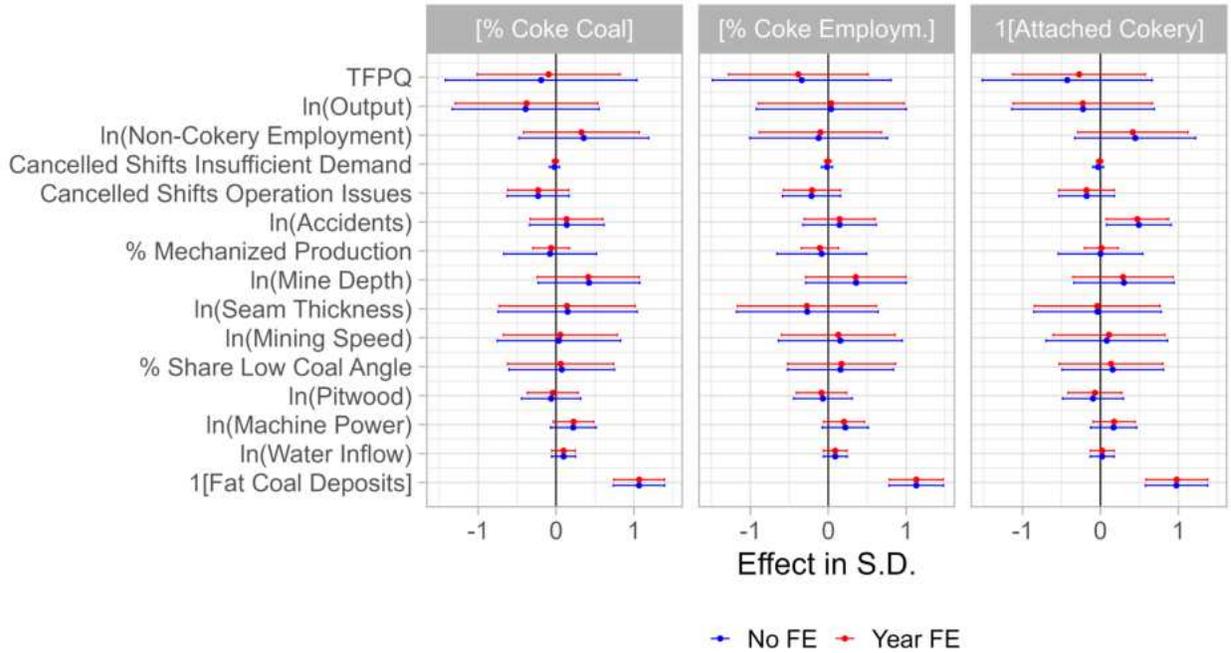


Figure 5: Selection into Treatment

Notes: This figure regresses cokery exposure on mine-year level variables for a sample of pre-policy data. Standard errors are clustered at the mine level and 90% confidence bands are reported.

by the average exposure of strictly positively treated mines.

3.2 Identification

We identify the causal effects of the policy under three assumptions. First, the assumption of parallel trends requires that highly- and less-exposed mines would have developed similar trends absent the policy. We provide suggestive evidence that this assumption is not violated based on the pre-trends of our dynamic difference-in-differences estimations.⁵ Callaway et al. (2024) has shown that the parallel trends assumption is more demanding for continuous treatment measures such as $[\%coking\ coal]_i$ and $[\%Cokery\ Employment]_i$. Using the binary exposure $\mathbb{1}[\text{Attached Cokery}]_i$, therefore, is an implicit robustness check for our two other continuous treatment definitions.

Second, the stable unit treatment variable assumption (SUTVA) requires that there are no spillovers of the treatment status of one mine on other mines. Spillovers in the treatment status

⁵Pre-trends will also be telling about reverse causality concerns. If outcome changes before the policy predict the treatment exposure, pre-trends would be either rising or falling.

per se, i.e., having or cokery or not, are unlikely as cokery availability and capacity are mainly pre-determined and unchangeable since cokery construction or expansion can take up to several years. However, the policy might also affect non-cokery mines as they can produce more coking-suitable coal in response to the policy. Those potential spillovers would then imply that our estimates are a lower bound of the treatment effect in absolute terms, giving net effects between more and less exposed mines.

Third, there should not be other shocks to the industry that take place at the same time and correlate with the exposure measures of the policy at hand. However, the main shock at this time in the industry was the establishment of the *Ruhrkohle AG*, a merger-to-one of 80% of the industry, which took place in 1968. The only part of the policy targeted explicitly at cokery mines, however, was the *Hüttenvertrag* (Gatzka, 1990), which we study in this paper. Hence, our analysis should not be confounded by other simultaneous shocks.

3.3 Measure of Productivity and Markups: Production Approach

As a main outcome of our analysis, we obtain quantity-based total factor productivity, i.e., TFPQ, by estimating a production function of coal mines using the control function approach (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Akerberg et al., 2015). Subsequently, we estimate markups and marginal costs using the production approach following De Loecker and Warzynski (2012).

We assume that mines produce coal Q_{it} with a Cobb-Douglas production technology⁶ $F(\cdot)$ using labor L_{it} , material M_{it} , and capital K_{it} :

$$Q_{it} = F(L_{it}, M_{it}, K_{it}; \boldsymbol{\beta}) \exp(\omega_{it}) = L_{it}^{\beta^L} M_{it}^{\beta^M} K_{it}^{\beta^K} \exp(\omega_{it}), \quad (3)$$

where ω_{it} is the unobserved Hicks-neutral productivity shock and $\boldsymbol{\beta} = (\beta^L, \beta^M, \beta^K)$. Herein, capital is a dynamic input, while labor and material are flexible inputs. We take advantage of mine-level physical data for both input and output information, which leaves our specification

⁶We later on also provide results based on a robustness check with a Leontief and a Translog production function.

free from the input/output price bias (Klette and Griliches, 1996; De Loecker and Goldberg, 2014). This benefit facilitates a consistent measure of the quantity-based total factor productivity, which purely reflects coal mines’ efficiency levels, and purges out demand-side factors embodied in prices. Specifically, the output is measured in tonnes of coal, labor is given by the number of miner shifts, capital by the machine power in kW, and material by the amount of pitwood in cubic metres.

To identify the coefficients of the production function, we follow the two-stage estimation procedure following Akerberg et al. (2015). Taking the logarithm of the production function, Eq.(3), and allowing for an unobserved term ϵ_{it} , which captures measurement error in output or unanticipated shocks to production, the estimating equation turns out to be:

$$q_{it} = \beta^L l_{it} + \beta^M m_{it} + \beta^K k_{it} + \omega_{it} + \epsilon_{it}. \quad (4)$$

We assume capital is chosen at period $t - 1$, while labor and material are decided at the current period t .

To control for the unobserved Hicks-neutral productivity ω_{it} , we construct a proxy by exploiting the material input demand equation, $m_{it} = m_t(l_{it}, k_{it}, \omega_{it}, \mathbf{z}_{it})$, where the vector \mathbf{z}_{it} includes all other variables that affecting the material demand (De Loecker, 2011; De Loecker and Warzynski, 2012; De Ridder et al., 2024). We collect the treatment variables ($Exposure_i, Post_t, Exposure_i \times Post_t$),⁷ a vector of dummies for the years relative to a new manager hiring ($Manager_{it-1}$), demand uncertainty measured by canceled shifts due to insufficient demand ($DemandUncertainty_{it}$), mine’s age, average wage, exit probability ($Exit_{it}$), longitude, and latitude of mines in the vector \mathbf{z}_{it} . Inverting the static material demand equation gives the control function for the Hicks-neutral productivity, $\omega_{it} = h_t(l_{it}, m_{it}, k_{it}, \mathbf{z}_{it})$, where $h_t(\cdot)$ is a nonparametric function. Substituting the control function of the unobserved productivity into Eq.(4), the first-stage estimation equation is:

$$q_{it} = \varrho_t(l_{it}, m_{it}, k_{it}, \mathbf{z}_{it}) + \epsilon_{it}, \quad (5)$$

⁷*Exposure_i* in our baseline analysis is the share of mine-level coal output used in the cokery process in pre-policy years.

where $\varrho_t(\cdot)$ is a nonparametric function of inputs and other variables. We run Eq.(5) by projecting the physical coal output on a high-order polynomial of the three inputs and other variables in \mathbf{z}_{it} to obtain estimates of expected output ($\hat{\varrho}_{it}$) and purge out measurement error ϵ_{it} .

In the second stage, we can compute the quantity-based productivity using $\omega_{it}(\boldsymbol{\beta}) = \hat{\varrho}_{ft} - \beta^L l_{it} - \beta^M m_{it} - \beta^K k_{it}$ given any value of $\boldsymbol{\beta}$. To identify production function coefficients and allow industrial policy exposures, new manager hiring, and demand uncertainty to affect productivity, we consider an endogenous first-order Markov process, $g(\cdot)$, to govern the law of motion for productivity following [De Loecker \(2011, 2013\)](#):

$$\omega_{it} = g(\omega_{it-1}, \mathbf{E}_{it-1}) + \xi_{it}, \quad (6)$$

where ξ_{it} denotes innovation in the productivity process and \mathbf{E}_{it-1} is a vector capturing all endogenous impacts on the productivity process, including $Exposure_i$, $Post_{t-1}$, $Exposure_i \times Post_{t-1}$, $Manager_{it-1}$, $DemandUncertainty_{it-1}$, and $Exit_{it-1}$. Note that the endogenous productivity process nests the typical exogenous process as a special case. Given $\boldsymbol{\beta}$, therefore, we can recover the innovation to productivity, $\xi_{it}(\boldsymbol{\beta})$, by nonparametrically regressing $\omega_{it}(\boldsymbol{\beta})$ on $\omega_{it-1}(\boldsymbol{\beta})$, and form moments that identify the parameters, using a generalized method of moments (GMM) estimator:

$$\mathbb{E} \left(\xi_{it}(\boldsymbol{\beta}) \begin{bmatrix} l_{it-1} \\ m_{it-1} \\ k_{it} \end{bmatrix} \right) = 0. \quad (7)$$

The instruments' exclusion restrictions are derived from the previously established timing assumptions regarding labor, material, and capital inputs. These assumptions posit that productivity innovation is orthogonal to the current capital and lagged labor and material inputs.

After obtaining the estimates of the production function, we can further compute markups following [De Loecker and Warzynski \(2012\)](#). Specifically, the markup can be expressed as $\mu_{it} := \frac{P_{it}}{\lambda_{it}} = \beta^X (\alpha_{it}^X)^{-1}$, where λ_{it} is the marginal cost, β^X refers to the output elasticity on any of the flexible input X and $\alpha_{it}^X := \frac{P_{it}^X X_{it}}{P_{it} Q_{it}}$ is the input expenditure share in revenue. P_{it}^X and P_{it} are input and output prices, respectively. However, what we observe in the data is

$\tilde{Q}_{it} := Q_{it} \exp(\epsilon_{it})$, which leads to the wrong measure of revenue shares. Therefore, considering the measurement error or unanticipated shocks in output, ϵ_{it} , the corrected revenue shares are given by $\hat{\alpha}_{it}^X = \frac{P_{it}^X X_{it}}{P_{it} \tilde{Q}_{it} / \exp(\epsilon_{it})}$. Using the corrected revenue shares, we compute markups μ_{it} ultimately. As we also observe P_{it} in the data, we further obtain unobserved marginal cost $\lambda_{it} = \frac{P_{it}}{\mu_{it}}$ following [De Loecker et al. \(2016\)](#).

4 Empirical Results

In this section, we conduct a difference-in-differences empirical strategy to identify the effects of reduced import competition on various dimensions of firm performance and organization of production for German coal mines.

4.1 Effects of Import Competition on Firm Performance

Productivity, Marginal Costs, and Markups. We take advantage of the available physical input and output information for coal mines to estimate quantity-based productivity. [Figure 6](#) presents the dynamic policy effects on TFPQ for different exposure specifications. The changes in quantity-based productivity display a parallel trend prior to the beginning of *Hüttenvertrag* that is statistically indistinguishable from zero. In contrast, productivity increased immediately and persistently in response to the policy intervention for coal mines with high exposure to the policy shock.

We quantify the policy effects on our mine-level outcomes by estimating [Eq.\(1\)](#) and present results in [Table 2](#). Column 1 shows that average exposure translates to significant efficiency gains by, on average, 5.4% to 6.4% post-policy, depending on different exposure specifications. Productivity effects grew over time and rose up to 10% in the later 1970s as we can see from [Figure 6](#).

The surprising post-policy efficiency gains are contrasted with the commonly observed positive association between competition and productivity. However, the significant productivity-enhancing pattern by the reduced import competition is robust to alternative production func-

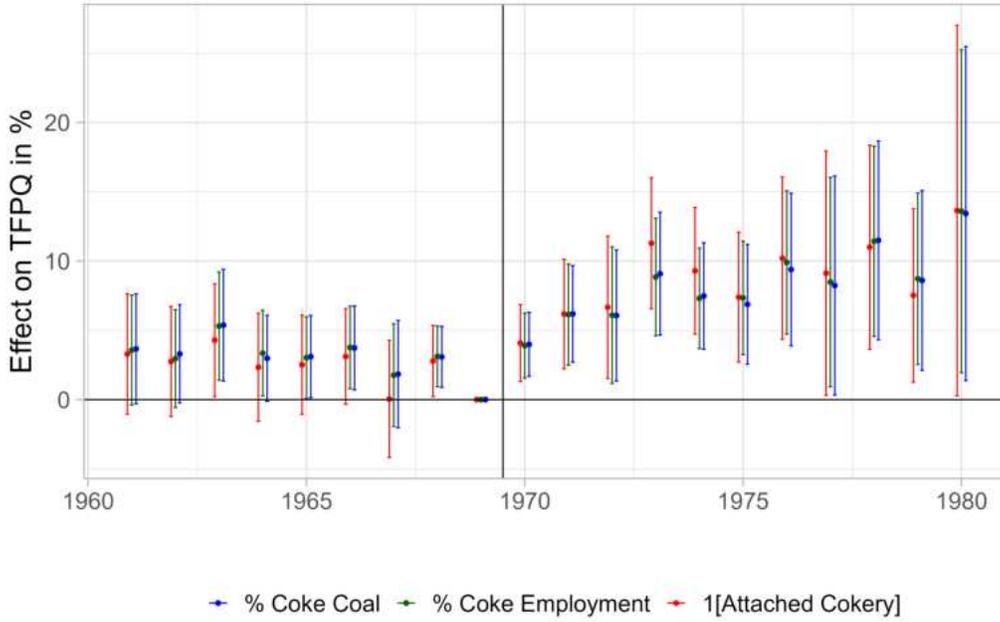


Figure 6: Effect of the *Hüttenvertrag* Policy on TFPQ

Notes: This figure gives the regression results of Eq.(2) with TFPQ as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported. TFPQ is estimated based on a Cobb-Douglas production function and estimation procedures, as shown in Section 3.3.

Table 2: Effects of the Policy on Productivity, Marginal Costs, and Markup

	ln(TFP) (1)	ln(Price) (2)	ln(MC) (3)	ln(Wage) (4)	ln(Markup) (5)
Panel A: % coking coal					
$Exposure_i \times Post_t$	0.046*** (0.014)	0.100*** (0.011)	-0.042** (0.018)	0.008 (0.007)	0.140*** (0.018)
Panel B: 1(Attached Cokery)					
$Exposure_i \times Post_t$	0.057*** (0.017)	0.098*** (0.012)	-0.047*** (0.018)	0.011 (0.007)	0.143*** (0.020)
Panel C: % Cokery Employment					
$Exposure_i \times Post_t$	0.048*** (0.014)	0.097*** (0.013)	-0.044*** (0.017)	0.008 (0.007)	0.138*** (0.017)
Mine FEs	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	884	975	884	975	884

Notes: *p<0.1; **p<0.05; ***p<0.01. Coefficients for the continuous exposures multiplied with the mean exposure for cokery mines to scale coefficients and standard errors.

tion specifications.⁸

To investigate whether coal mines pass on their productivity gains to consumers, we employ the production approach, as we presented in Section 3.3, to measure markups and marginal costs. We use labor as the flexible variable input to estimate markups at the coal mine level. As we directly observe the coal output price information, we can compute marginal costs at the coal mine level by dividing observed coal prices by the estimated markups. We first discuss changes in output prices. Given that prices vary by coal type and between coal and refined coke, we create a mine-year level output price by weighting coal-type specific prices by share of production. Column 2 of Table 2 shows that output prices increased by 10% in response to the reduced import competition, which aligns with the common intuition that decreased competitive pressures through the intervention of *Hüttenvertrag* will raise prices. In the spirit of the trade liberalization literature (De Loecker et al., 2016; Brandt et al., 2017), the price effect could be decomposed into changes in markups and efficiency within the firm. Thus, we subsequently use the estimated markups and marginal costs information to examine both channels directly.

We begin by focusing on changes in marginal costs reported in Column 3. On average, our difference-in-differences estimate in the marginal cost regression fell by 5% in response to the policy intervention. Marginal cost changes can be attributed to changes in either production efficiency or input prices. We specifically examine changes in input prices—mine wage—in Column 4 and find it is not significantly affected, which suggests that changes in marginal costs were primarily derived from the efficiency gains we showed in Column 1. The reduction in marginal costs translates to cost savings of 4.5 billion DM in cokery mines in the post-policy years until 1980—which, by far, exceeds the overall sum of price differences between German and world market prices compensated by the government throughout this period.

Note that if markups were constant, the decline in marginal costs would translate to decreases in output prices. However, Column 5 shows that markups rose even more than prices by around 5%. This is to be expected, given that prices are precisely the sum of marginal costs and markups (all in logs). The point estimates in Columns 3 and 5 sum to the coefficient in Column 2. Thus,

⁸In Figure A1 in the Appendix, we provide more details of alternative production function specifications, including a Translog production function and a Leontief production function following De Loecker and Scott (2022), where we assume that pit wood materials are not substitutable with labor and capital.

a negative point estimate of marginal costs maps to a larger coefficient in the markup regression than the coefficient for prices in Column 2. The results imply that coal mines offset the cost savings from the efficiency gains by raising markups rather than passing on the efficiency gains completely to consumers. At least in the short run, the *Hüttenvertrag* policy hence benefited upstream coal mines relatively more than downstream steel producers or other consumers.

Anti-Competitive Effects. The overall effect of the *Hüttenvertrag* policy on markups combines the anti-competitive and efficiency effects. It is worth noting that drawing conclusions about the anti-competitive effects from the markup regressions would be misleading (De Loecker et al., 2016).⁹ Since the marginal costs are not controlled, the policy intervention could affect costs through efficiency effects and ultimately induce firms to adjust markups, which leads to endogeneity issues for identifying anti-competitive effects. Hence, we explicitly control marginal costs to isolate the anti-competitive effects. The results are reported in Table 3. The coefficient in Column 2 is positive but slightly smaller than that of Column 1, the point estimate of the markup regression without controlling marginal costs, and we duplicate reporting here for clarity. In Column 3, we instrument marginal costs with a higher-order polynomial in lagged marginal costs similar to De Loecker et al. (2016) to deal with potential measurement error, and the results are qualitatively the same. This suggests that the increased markups were mainly derived from the anti-competitive effect of the *Hüttenvertrag* policy, which indeed reduced import competition.

Productivity Dispersion. While we showed that highly exposed mines increased TFPQ in response to the policy intervention, the average effect on productivity is not informative enough to speak to the policy effect on TFPQ dispersion. To study the effect of the policy along the whole productivity distribution, we apply the distribution regression method by Chernozhukov et al. (2013) to estimate the counterfactual distribution absent the policy. The methodology has been widely adopted to estimate the distributional effects of public policies in different contexts,

⁹De Loecker et al. (2016) discuss the identification of trade liberalization’s pro-competitive effects. In contrast, we study an anti-trade liberalization policy scheme leading to anti-competitive effects, but the spirit of examining how prices, markups, and marginal costs responded to the policy intervention is consistent and applicable.

Table 3: Anti-Competitive Effects of the Policy

	ln(Markup) (1)	ln(Markup) (2)	ln(Markup) (3)
Panel A: % coking coal			
$Exposure_i \times Post_t$	0.140*** (0.018)	0.119*** (0.013)	0.113*** (0.014)
First-stage F -test			27.4/13.8
Panel B: 1(Attached Cokery)			
$Exposure_i \times Post_t$	0.143*** (0.020)	0.117*** (0.014)	0.110*** (0.016)
First-stage F -test			27.2/13.8
Panel C: % Cokery Employment			
$Exposure_i \times Post_t$	0.138*** (0.017)	0.115*** (0.015)	0.109*** (0.015)
First-stage F -test			27.3/13.8
Mine FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Second-order polynomial of MC	No	Yes	Yes
Instruments	No	No	Yes
Observations	884	884	779

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Coefficients for the continuous exposures multiplied with the mean exposure for cokery mines to scale coefficients and standard errors. F -statistic of first stage is reported for marginal cost and squared marginal cost separated by a /-sign.

such as [Dube \(2019\)](#) and [Fischer et al. \(2025\)](#). In a difference-in-differences regression, one can estimate the effect of TFPQ lying below or above a certain TFPQ threshold, c , by changing the outcome variable in Eq.(2):

$$\mathbb{1}[TFPQ_{it} \leq c] = \beta Exposure_i \times Post_t + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (8)$$

The adapted outcome variable equals 1 if TFPQ is below or equal to a chosen threshold value and 0 otherwise. Estimating the effect for all realizations as thresholds and subtracting the estimated treatment effect to the actual TFPQ distribution gives the counterfactual distribution.

Figure 7 gives the observed and estimated TFPQ distributions for the three exposure vari-

ants. In all three specifications, the left tail of the TFPQ distribution is affected the most. Hence, the policy intervention increased TFPQ for formerly less productive coal mines and, by that, decreased productivity dispersion.

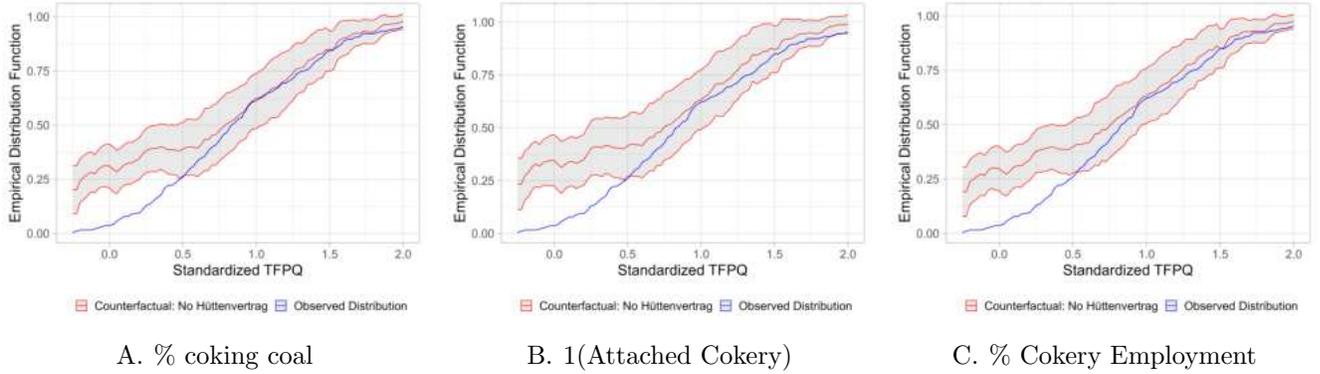


Figure 7: Distributional Effect of the *Hüttenvertrag* Policy on Productivity

Notes: This figure gives the distribution regression results of Eq.(2) following Chernozhukov et al. (2013). Standard errors are clustered at the mine level and 90% confidence bands are reported.

Reallocation. Given we found that low-productivity coal mines increased productivity in response to the policy, we investigate whether low-productivity mines also increased their market share. To check this, we conduct a heterogeneity analysis for output market shares by the degree of pre-policy productivity. We assign coal mines with a below-median TFPQ in the pre-policy year 1968 into the low-TFPQ group and others to the high-TFPQ category. Results are reported in Figure 8. It shows that coal mines that had a high exposure to the policy and a below-median TFPQ in the pre-policy year increased their market shares significantly. In contrast, exposed high-TFPQ coal mines kept market shares unchanged in response to the policy intervention. The coal mines in the low-TFPQ group captured more market shares from non-cokery coal mines and mines which exited the market.

4.2 Effects of Import Competition on Organization of Production

Exit Analysis: Survival Probability. We now examine the effect of the *Hüttenvertrag* policy on survival probability of coal mines. We focus on studying exit rather than entry because only one coal mine entered throughout our sample, given the high setup costs of a mine in the

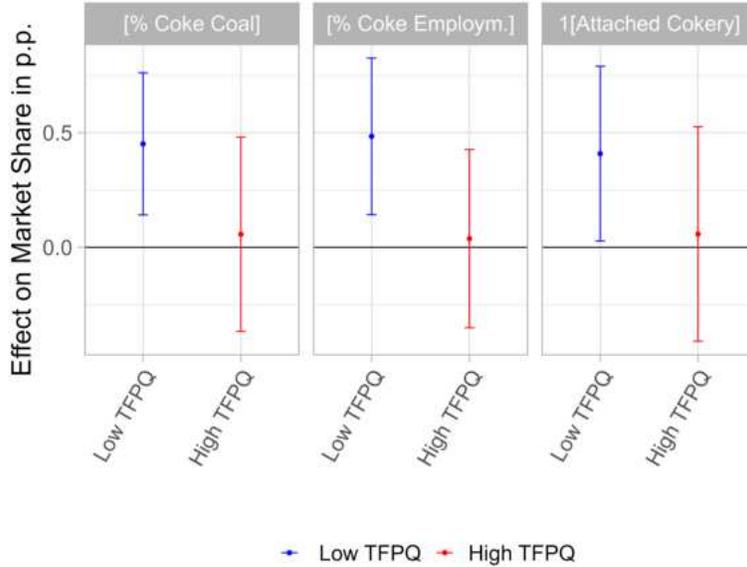


Figure 8: Effect of the *Hüttenvertrag* Policy on Market Share by Productivity Level

Notes: This figure gives the regression results of Eq.(2) with market share (in terms of output) as an outcome - heterogeneity by the degree of TFPQ in the pre-policy year 1968. Standard errors are clustered at the mine level and 90% confidence bands are reported.

declining German coal mining industry context (Fischer, 2024). Specifically, we estimate Eq.(2) by setting up the outcome variable to be 1 if a coal mine operated in year t and zero if it exited in t or before. Figure 9 presents the effect of the policy on the likelihood that a coal mine operates in a given year for all mines that have been active in our sample for at least three years. Indeed, a higher cokery exposure leads to a significantly higher survival probability post-policy of up to 20% ten years post-policy.

Figure 10 further shows that the policy has heterogeneous implications for the survival probability of coal mines with different levels of pre-policy productivity and demand uncertainty. In Panel A, using the same low- and high-TFPQ classification as before, we find that the *Hüttenvertrag* policy significantly increased low-TFPQ cokery mines' survival probability by around 50 percentage points depending on different exposure specifications, while high-TFPQ coal mines were not significantly affected. This aligns well with what we found before regarding the heterogeneous policy effects on both productivity dispersion and market reallocation: Only low-TFPQ coal mines became more productive and captured higher market shares, ultimately leading to higher survival probabilities.

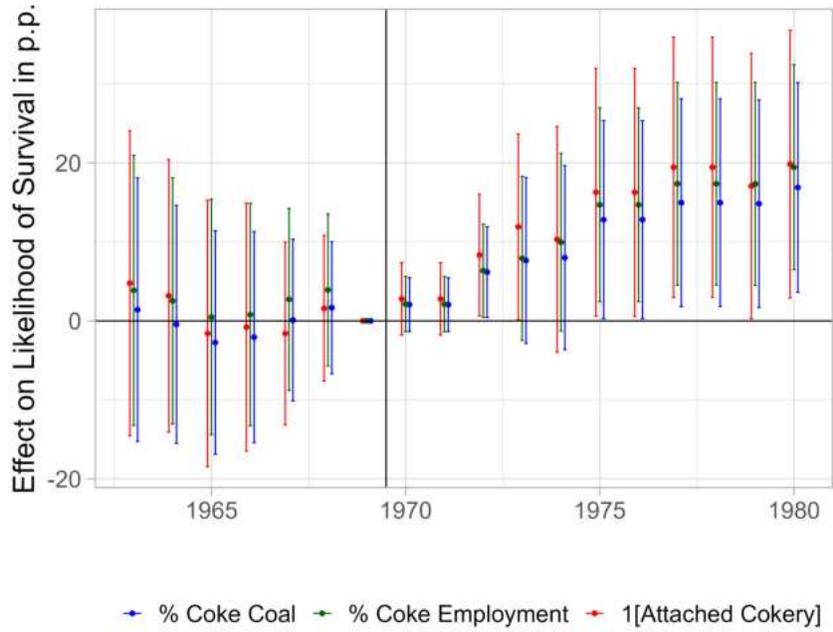


Figure 9: Effect of the *Hüttenvertrag* Policy on Survival

Notes: This figure gives the regression results of Eq.(2) with survival as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

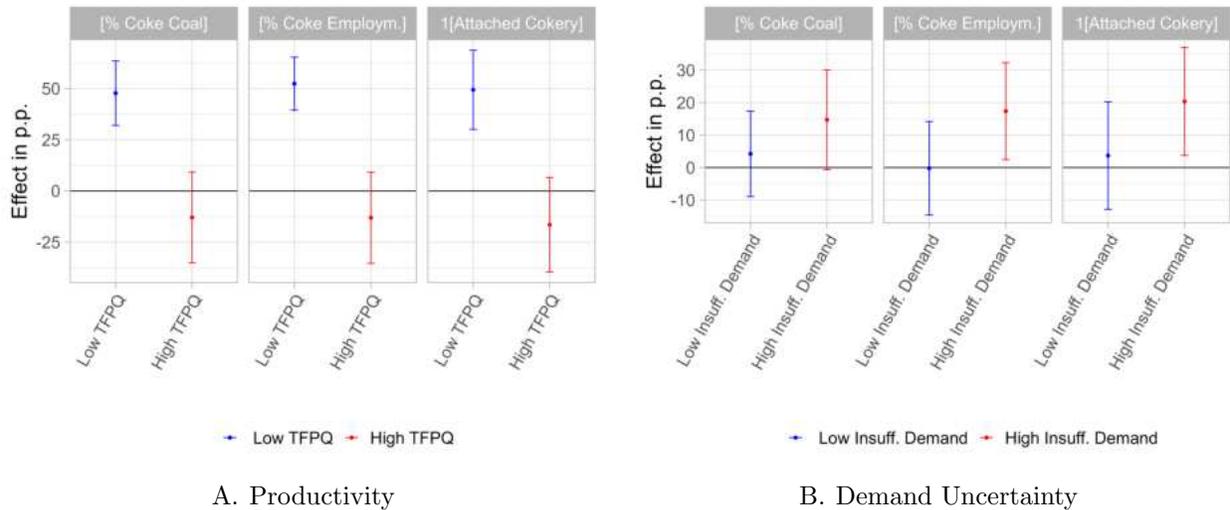


Figure 10: Effect of the *Hüttenvertrag* Policy on Survival: Heterogeneity Analysis

Notes: This figure gives the regression results of Eq.(2) with survival as an outcome - heterogeneity by the degree of pre-policy productivity (left panel) and demand uncertainty (right panel). Standard errors are clustered at the mine level and 90% confidence bands are reported.

We also examine the heterogeneity analysis by the degree of pre-policy demand uncertainty. We utilize a novel and granular measure of demand uncertainty at the establishment level, i.e., canceled shifts due to insufficient demand, which we directly observe in our data. The canceled shifts due to insufficient demand reflect the misalignment between expected labor use prior to production and actual labor use after product demand is revealed. This misalignment is proportionate to unexpected demand shocks, and we refer to it as demand uncertainty. Thus, we classify coal mines with an above-median share of canceled shifts due to insufficient demand in the pre-policy years (1960 to 1969) into the high insufficient demand group and the remaining into the low counterpart.

In Panel B of Figure 10, we show that cokery mines with high demand uncertainty prior-policy experienced an increase in the survival likelihood by more than 20 percentage points. In contrast, the survival probabilities of cokery mines with below-median prior-policy demand uncertainty were not significantly affected by the policy intervention. This is unsurprising and consistent with what we found in Panel A, as productivity and demand uncertainty are negatively correlated. In Section 6.1, we further examine the impact of policy on demand uncertainty and the role of management practices in shaping this relationship.

Output, Employment, and Mine Scope. The increased productivity in response to the *Hüttenvertrag* policy is robust and consistent across different specifications, while one might attribute the pattern to the economy of scale. To examine this point, we study how the policy affects the output, employment, and mine scope of highly exposed mines relative to less exposed mines. Figure 11 summarizes the results on a battery of outcome variables related to different output and scope measures.

First, we show that the policy did not affect the number of operation days for coal mines. Second, we use two different output measures, (i) raw output including coal and non-coal content quarried, and (ii) output of coal only, respectively, as dependent variables to examine the policy effects. The results indicate that both output measures were not significantly affected by the policy intervention. Third, neither overall employment nor the number of workers underground the mine (below the surface) was affected by the policy. Finally, the policy also did not impact

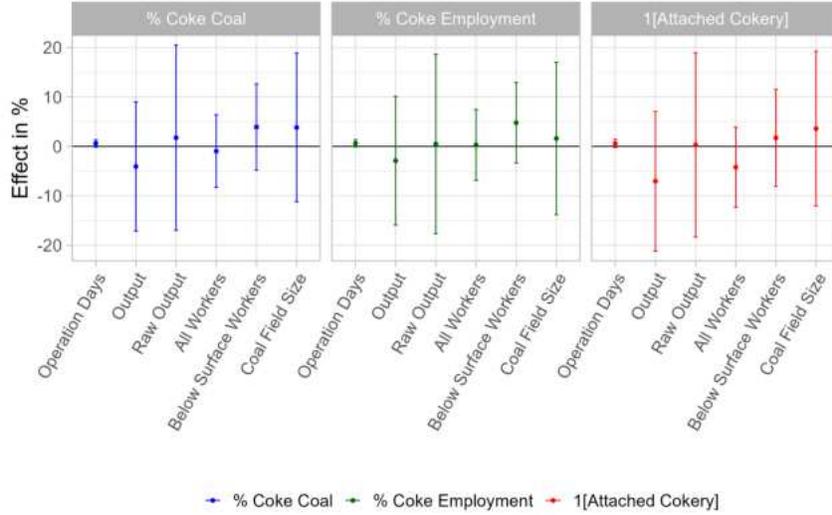


Figure 11: Effect of the *Hüttenvertrag* Policy on Output and Employment

Notes: This figure gives the regression results of Eq.(2) with output and miner employment as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

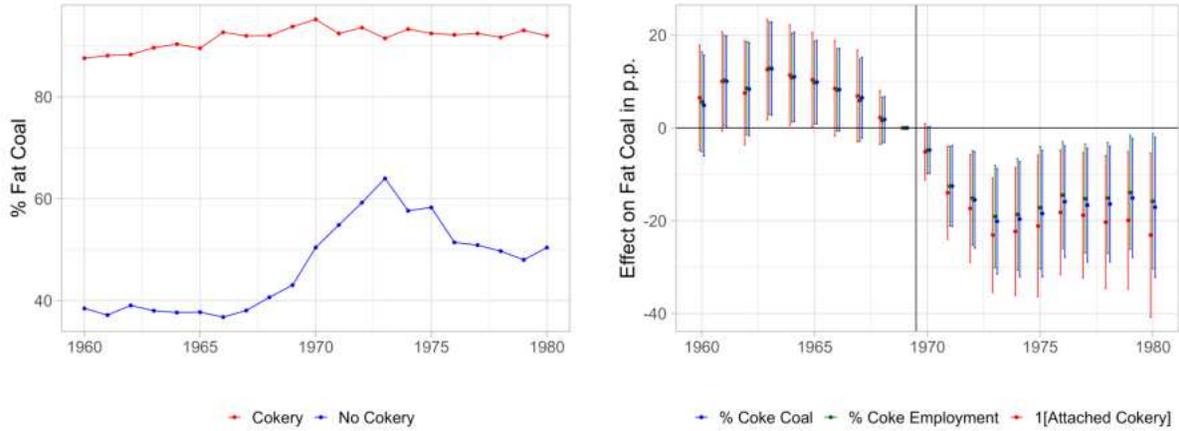
the size of the coal field significantly.

In sum, all the output and scope measures were not significantly affected by the *Hüttenvertrag* policy, which rules out the potential mechanism of the economy of scale for explaining the increased productivity. In Section 5, we further investigate the underlying mechanism and show that management practices significantly drive the productivity surge in response to the *Hüttenvertrag* policy.

Strategic Response of Non-Cokery Mines. While mines without cokeries cannot coke themselves, they could still be incentivized to quarry coking coal and sell to coking plants of other mines or steel companies. Hence, they might also have an incentive to switch to producing coking coal that can be used for coke production.

Fat coal is the type of coal that is most often used as coking coal to produce coke (Fritzsche et al., 1952). While not every coal mine can find fat coal in its coalfield, some mines could reallocate their production towards a higher production share of fat coal. Figure 12 shows two facts. The left panel shows that cokery mines, almost 100%, quarried fat coal even before the policy, while non-cokery mines only quarried fat coal to the extent of around 40% before the policy. However, after the policy was rolled out, the share of fat coal production also increased strongly in non-

cokery mines. The pattern is also supported by the difference-in-differences results in the right panel, which shows that the share of fat coal in high-exposure mines fell immediately in response to the policy intervention relative to less-exposed mines. This significant drop in the share of fat coal is apparently due to the surge of the share of fat coal in less-exposed coal mines.



A. Share of Fat Coal by Cokery Status

B. Share of Fat Coal - Dynamic Effects

Figure 12: Effect of the *Hüttenvertrag* Policy on Fat Coal Production

Notes: This figure presents the trend in fat coal production over time by cokery status and gives the regression results of Eq.(2) with the share of fat coal as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

Note that this evidence shows that the SUTVA is violated as the policy intervention also effectively treated less-exposed mines to some extent. Hence, we consider our estimates a lower bound for the treatment effects.

5 The Role of Management Practices: Mechanisms

This section examines the underlying mechanism of the increased productivity derived from the reduced import competition and shows that management practices are the primary channel driving the productivity surge.

5.1 Manager Change in Response to Import Competition

A large strand of literature has shown that manager behavior impacts establishment- and firm-level productivity (Bloom and Van Reenen, 2007, 2010; Bloom et al., 2016b, 2020; Fenizia, 2022; Demirer and Karaduman, 2024). In this section, we take advantage of a rich dataset of coal mines with employer-employee-matched information on managers to examine whether the policy intervention induced changes in the composition of the managing board of mines. In our setting, the managing board encompasses the heads of the mine and cokery (if applicable), i.e., mine and cokery directors. On average, a mine has two directors in our sample.

We focus on the manager change in response to the *Hüttenvertrag* policy at the first available post-policy year, i.e., 1970, as the dynamic policy effects on hiring, see Figure A2 in the Appendix, show an immediate and significant increase in managerial changes post-policy, followed by a decrease and return to normal afterward.¹⁰ To examine so, we adapt Eq.(1) to be:

$$Y_{it} = \beta_1 Exposure_i \times \mathbf{1}[Year_t = 1970] + \beta_2 Exposure_i \times \mathbf{1}[Year_t > 1970] + \alpha_i + \lambda_t + \varepsilon_{it}. \quad (9)$$

Figure 13 presents the effects of the policy intervention on changes in the number of newly hired managers right after the policy announcement, i.e., β_1 is reported.

Three patterns emerge. First, we find a positive effect of the policy exposure on the number of newly hired managers when looking at the overall sample of new managers (blue). The effect is sizable with a point estimate of 0.6-0.7 new managers in exposed mines relative to non-exposed mines right after the policy, which suggests that treated mines hired new managers in response to the policy shock.

Second, we study heterogeneity in the hiring of new managers based on their ability. To disentangle mine-specific potential for productivity and manager ability, we proxy manager

¹⁰Since the manager data is only available for every second year, 1970 is the first available post-policy year. Demirer and Karaduman (2024) also find a similar immediate increase in managerial changes post-acquisition for power plants.

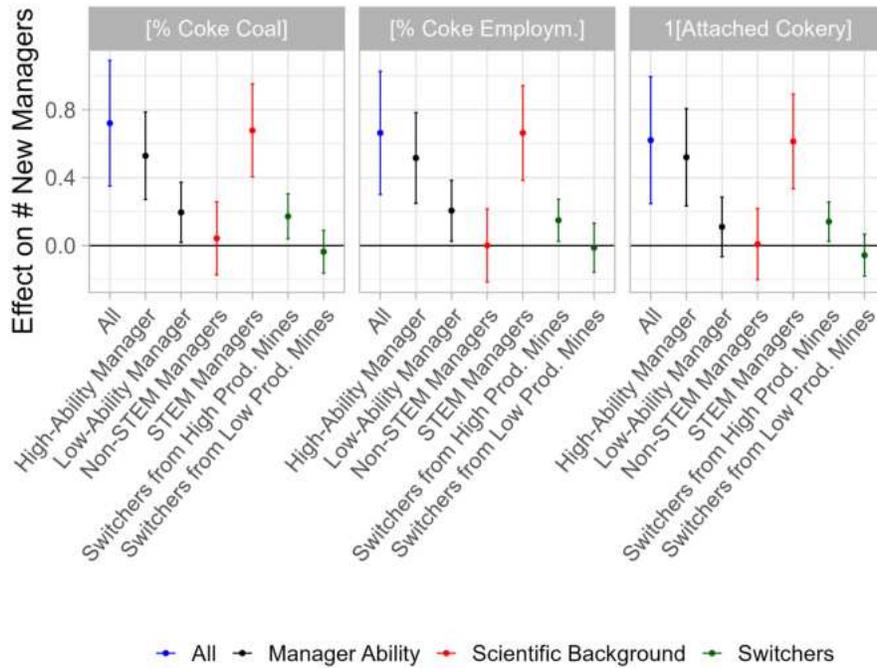


Figure 13: Effect of the *Hüttenvertrag* Policy on Hiring of New Managers

Notes: This figure gives the effect of the policy on the number of new managers and switchers from other mines. In the left panel, we regress the outcome (number of new managers) on two treatment effect dummies, once the treatment exposure interacted with a year dummy for the year 1970 and once with a dummy for years after 1970. The treatment effect for the first post-policy year 1970 is reported in the figure then. It further provides evidence on the heterogeneity of new hirings depending on the pre-policy degree of demand uncertainty. Standard errors are clustered at the cokery level and 90% confidence bands are reported.

ability in a regression approach in the style of [Bertrand and Schoar \(2003\)](#)¹¹:

$$TFPQ_{it} = \lambda_i + \gamma_t + \phi_m + \epsilon_{it} \quad (10)$$

where we regress mine-level TFPQ on mine-level (λ_i), year (γ_t)¹², and manager (ϕ_m) fixed effects. The estimated manager FE give our proxy of manager ability, i.e., their contribution to mine productivity. Importantly, manager fixed effects can only be identified if managers do not stay with the same mine throughout the sample and if managers do not have identical employment histories¹³. However, we are particularly interested into the productivity of newly hired managers (switchers or outside hires), making this concern less problematic in our setting.

Figure 13 indeed shows that mostly above-median ability managers are hired in response to the policy.

Third, to further assess new hires' managerial characteristics, we distinguish managers into two groups based on their STEM backgrounds. We re-estimate Eq.(9) with different outcome variables of the number of new (non-)STEM managers (red). We find that the newly hired managers of the cokery coal mines primarily had STEM backgrounds. This is especially reasonable for the coal mining context, as managers with STEM backgrounds tend to have better knowledge about engineering, especially coal mining engineering and technology ([Rubens, 2023a](#)). There also have been several mining schools in Germany giving managers where one could graduate with a mining engineering diploma.

Third, given the availability of detailed employer-employee-matched information on managers for coal mines, we can track managers by name and further identify job switchers between mines. Similarly, we classify new managers into two groups conditional on whether they come from more productive former employers and re-estimate Eq.(9) (green). We find that cokery coal mines significantly hired new managers from other mines with higher productivity than

¹¹While the intuition of this approach is similar to [Abowd et al. \(1999\)](#), we rely on firm- instead of worker-level productivity proxies for the estimation and rely to a stronger extend on manager switches between establishments following [Bertrand and Schoar \(2003\)](#).

¹²We add time fixed effects to the standard approach by [Bertrand and Schoar \(2003\)](#) to account for trends in average productivity (e.g., mechanization and exit).

¹³We drop managers with these criteria from the sample leaving us with estimates of ability for 72% of all new managers.

themselves. In contrast, no significant effect is found on the likelihood of managers coming from establishments with lower productivity. This indicates that managers come from more productive mines, potentially bringing knowledge of new technology and advanced experience in various aspects of mine improvement.

5.2 What Predicts Manager Change?

In this section, we explore why coal mines decided to change managers in response to the policy intervention. Figure 14 reports the heterogeneous effects of the *Hüttenvertrag* policy by pre-policy demand uncertainty levels. We find that only mines with high pre-policy demand uncertainty—again measured by the share of canceled shifts due to insufficient demand—responded to the policy by hiring more new managers. Combining what we found from Section 5.1, this suggests that coal mines suffering from high demand uncertainty tend to hire new and better managers with more technical knowledge, such as those with STEM backgrounds and/or from more productive former employers.

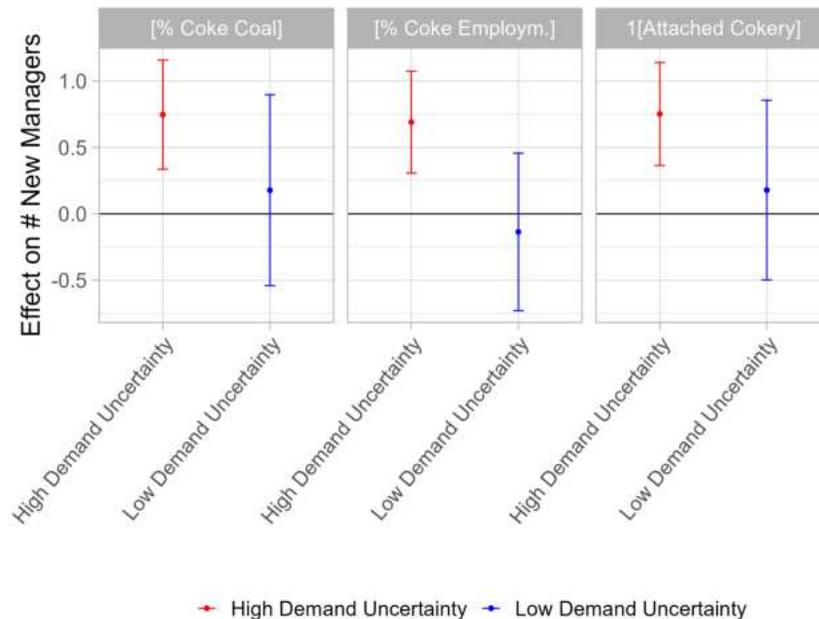


Figure 14: Effect of the *Hüttenvertrag* Policy on Hiring of New Managers: Heterogeneity Analysis

Notes: This figure gives the effect of the policy on the number of new managers depending on the pre-policy degree of demand uncertainty. Standard errors are clustered at the cokery level and 90% confidence bands are reported.

5.3 Effects of Manager Hirings

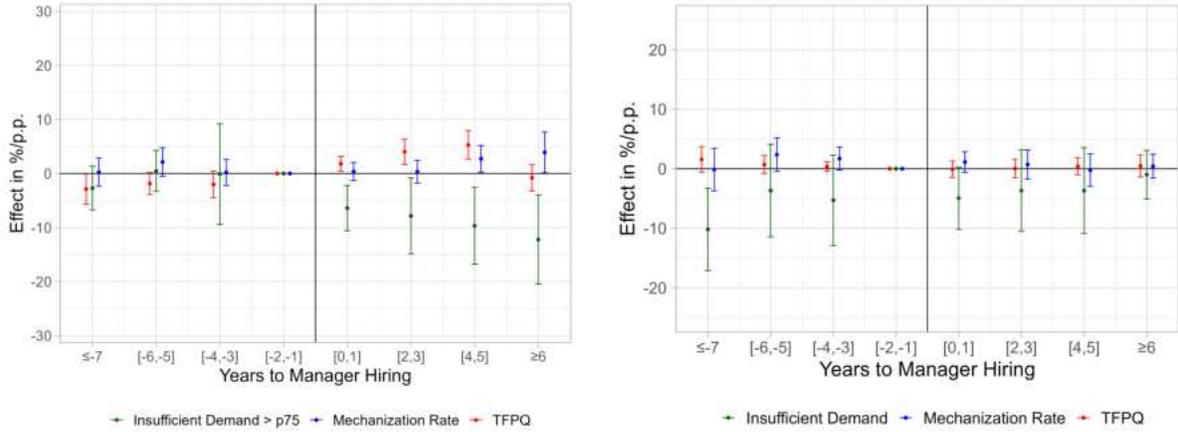
We found that cokery mines hired more new and better managers reacting to the *Hüttenvertrag* policy. Though much literature has found evidence that good management can improve firm performance (Bloom and Van Reenen, 2010), it is still unclear if this is also true in the German coal mining industry. To speak to this, we conduct an event study of manager hiring for coal mines by augmenting Eq.(2) into the form:

$$Y_{it} = \sum_{k=-7, \neq 1}^6 \beta_k \times Manager_{it+k} + \sum_g \beta^g \times Exposure_i^g \times \mathbb{1}[Year_t > 1969] + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (11)$$

where $Manager_{it+k}$ is an indicator that equals 1 for coal mine i in year $it+k$ hired at least one new manager and 0 otherwise. The coefficients of the interest, β_k , in the specification represent differences in the dependent variables between coal mines with and without hiring a new manager each year. We control for the baseline difference-in-differences-related terms for the three treatment variants, g , used to isolate the policy effects.

We estimate Eq.(11) for cokery coal mines and non-cokery coal mines separately. Figure 15 reports the results. In Panel A, we run the dynamic effect of manager hiring in cokery mines post-policy on TFPQ, mechanization rate, and the probability of having a very high share of shifts canceled due to insufficient demand, conditional on all three difference-in-differences exposure specifications. We find that a manager hiring event in a cokery mine can lead to a significant and persistent increase in mechanization rate by up to 5 percentage points, while TFPQ increased for several years by up to 7% in response to manager hiring. In contrast, the probability of having a very high demand uncertainty decreased by more than 10 percentage points persistently after a manager’s hiring. This suggests that hiring new managers for cokery coal mines indeed decreased demand uncertainty, increased mechanization, and ultimately boosted productivity.

In Panel B, we instead focus on non-cokery coal mines, which were less exposed to the policy intervention. Following Eq.(11), we conduct the same estimation for non-cokery coal mines. Interestingly, we still find significant and persistent increases in TFPQ for non-cokery



A. Cokery Coal Mines

B. Non-Cokery Coal Mines

Figure 15: Effect of Manager Hiring on Mine-Level Outcomes

Notes: This figure gives the regression results of an event study of manager hiring for coal mines. Endpoints of the event study are binned (Schmidheiny and Siegloch, 2023). The 75th percentile of insufficient demand calculated based on observations with a positive, non-zero share of canceled shifts due to insufficient demand. Standard errors are clustered at the mine level and 90% confidence bands are reported.

coal mines after a manager’s hiring. However, we did not find that the manager hiring event affected the mechanization rate and probability of high demand uncertainty, which is different from what we found for cokery coal mines. This indicates that manager hiring without reduced import competition does not significantly affect demand uncertainty and mechanization rate. In Section 6, we illustrate that demand uncertainty and mechanization rate are two essential outcomes for managers to consider in response to the *Hüttenvertrag* policy.

We further provide evidence in the Appendix (see Figure A3) showing that manager hiring cause substantial investments into mines and cokeries. Manager hirings in cokery mine post-policy lead to more conveyor tunnels (up to 15%) and an extended cokery capacity (up to 25%) - substantial investments in mine infrastructure. The average volume and scale per mining point also increases by up to 10%, reflecting a turn towards large-scale production.

5.4 The Management Channel Between Import Competition and Firm Performance: Productivity and Markups

We now show that management is essential in facilitating firm performance in response to the reduced import competition due to the *Hüttenvertrag* policy. We focus on the most fundamental dimensions of firm performance: productivity and markups.

To show and quantify to what extent management changes explain the policy effects, we employ the causal steps approach (Baron and Kenny, 1986; Alesina and Zhuravskaya, 2011; Jiang and Zhang, 2024) to re-estimate our main difference-in-differences analyses, once with and once without controlling for manager changes. Controlling for manager changes implies that we add a variable counting the number of managers hired to the baseline difference-in-differences estimation. Figure 16 shows that controlling for the manager changes absorbs treatment effects on both productivity and markups. Especially for productivity, controlling the manager changes induces the whole treatment effects to disappear, which indicates that manager changes play an essential role in explaining the observed productivity surge in response to the reduced import competition.

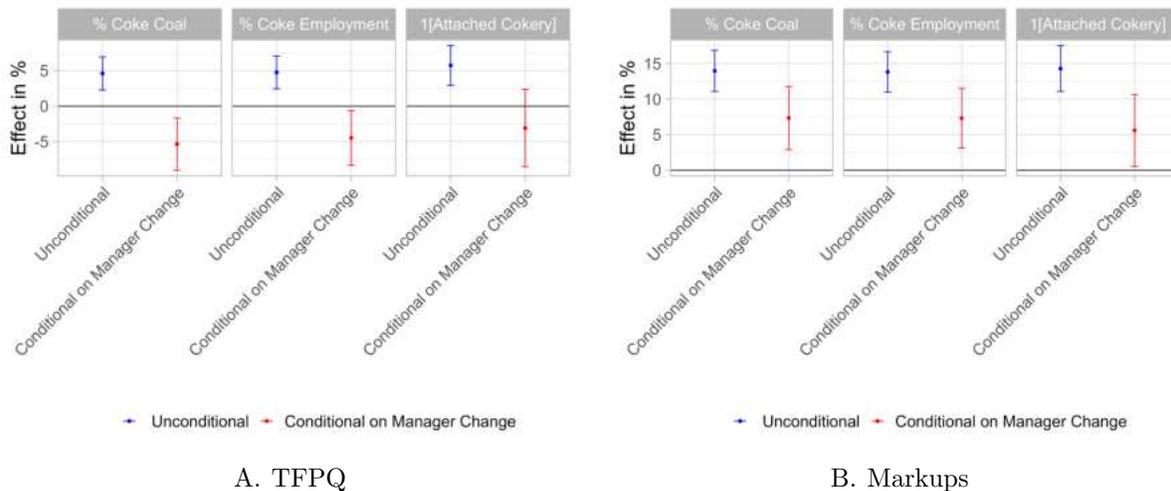


Figure 16: Effect of the *Hüttenvertrag* Policy on Outcomes (un)conditional on Manager Changes

Notes: This figure gives the effect of the policy (un)conditional on manager hirings Standard errors are clustered at the cokery level and 90% confidence bands are reported.

We further present the heterogeneity analysis by interacting exposure variables with the

intensity of new managers hired (i.e., few new managers hired vs. many new managers hired). If management matters in explaining the changed patterns of firm performance, we would expect coal mines with different magnitudes of manager hiring to show heterogeneous policy effects. In Figure 17, we interact the treatment effect with dummies that whether the treated cokery coal mines hired fewer or more managers than the median number of manager changes post-policy, respectively. We indeed find that the policy effects on both productivity and markups are especially strong in those mines that hired more new managers after the policy. Hence, we conclude that management practices are an essential channel for explaining efficiency gains in response to reduced import competition. In the subsequent section, we examine how managers improve firm performance under such less competitive markets.

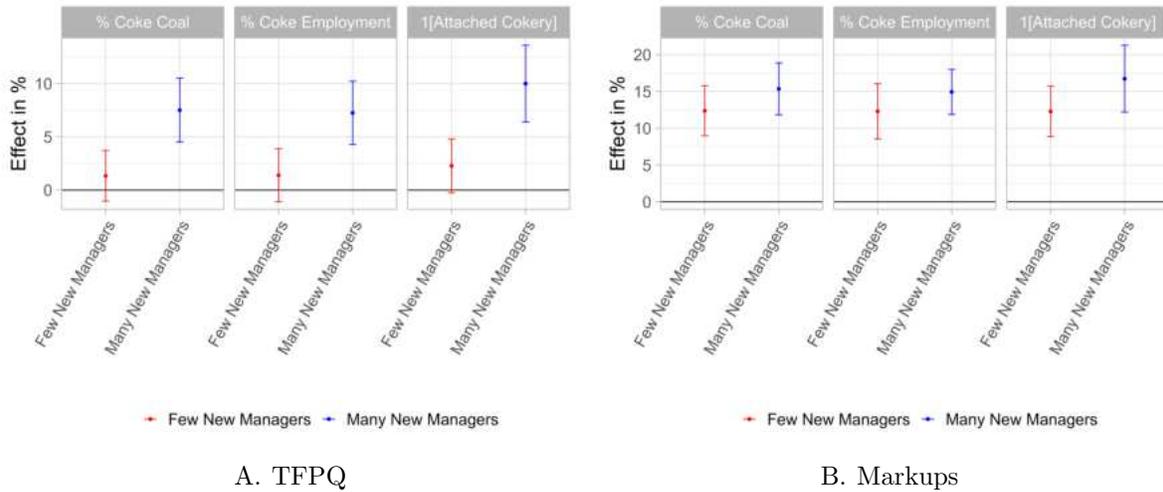


Figure 17: Effect of the *Hüttenvertrag* Policy on Outcomes - Depending on Number of Manager Changes

Notes: This figure gives the effect of the policy where we interact the policy treatment dummy with a dummy for low and high number of manager hirings. Standard errors are clustered at the cokery level and 90% confidence bands are reported.

6 How Do Managers Improve Firm Performance?

Our analyses in previous sections have demonstrated that the *Hüttenvertrag* policy reduced import competition and incurred efficiency gains for cokery coal mines, which are primarily driven by manager changes. In this section, we answer the question of how managers realize

these efficiency gains under the reduced import competition.

6.1 Demand Uncertainty

In Section 4.2, we found that cokery mines with high prior-policy demand uncertainty experienced a significant increase in the survival probability. At the same time, in Section 5.2, we found that these mines also hired more new managers in response to the reduced import competition. Now, we examine whether these newly hired managers helped reduce demand uncertainty post-policy. We still use the unique information on the canceled shifts due to insufficient demand to measure demand uncertainty. Given that coal mines had many zeros in the record of canceled shifts in good economic times, we consider both the policy’s extensive and intensive margin effects on demand uncertainty. Both specifications indicate consistent results and implications.

We start from the extensive margin. By comparing the reported number of canceled shifts with different thresholds, i.e., zero or upper tercile (p67) of the annual distribution of canceled shifts due to insufficient demand, we have $\mathbb{1}[\text{Demand Uncertainty} > 0]$ and $\mathbb{1}[\text{Demand Uncertainty} > \text{p67}]$, respectively. Figure 18 shows the results by estimating Eq.(1) condition on these two dependent variables. We find that the extensive margin effects of the policy are uneven across different percentiles of the distribution of demand uncertainty—the *Hüttenvertrag* policy significantly decreased the probability for a cokery mine being in the group with very high demand uncertainty.

We also check the intensive margin. Figure 19 presents the effects of the *Hüttenvertrag* policy on the demand uncertainty. In Panel A, we first estimate Eq.(1) without manager hiring controls (blue). The intensive margin shows that the policy intervention significantly reduced cokery coal mines’ demand uncertainty. In contrast, once we control the manager hiring as before (red), all the significant policy effects are gone, which suggests that management practices are the primary reason explaining the reduced demand uncertainty.

In Panel B, we further examine the heterogeneity analysis by the intensity of the number of new managers hired. We find that cokery mines with more new managers hired reduced their

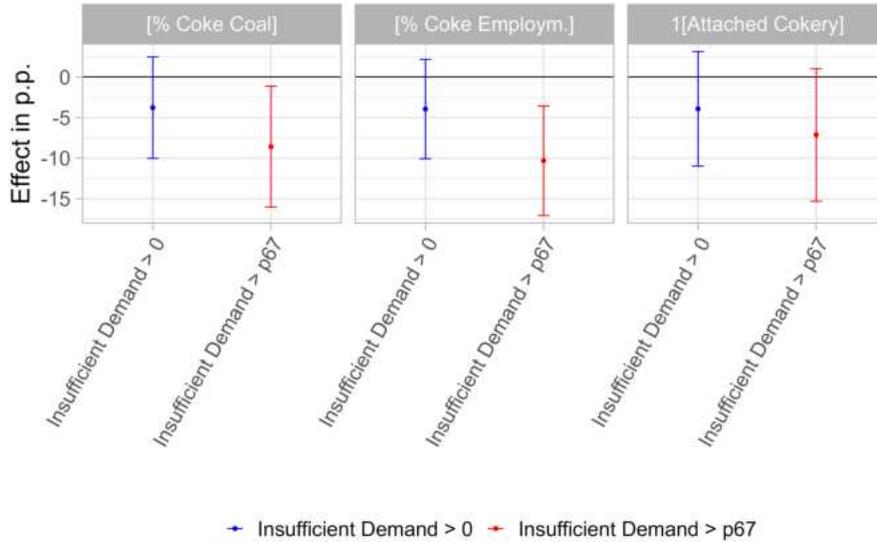


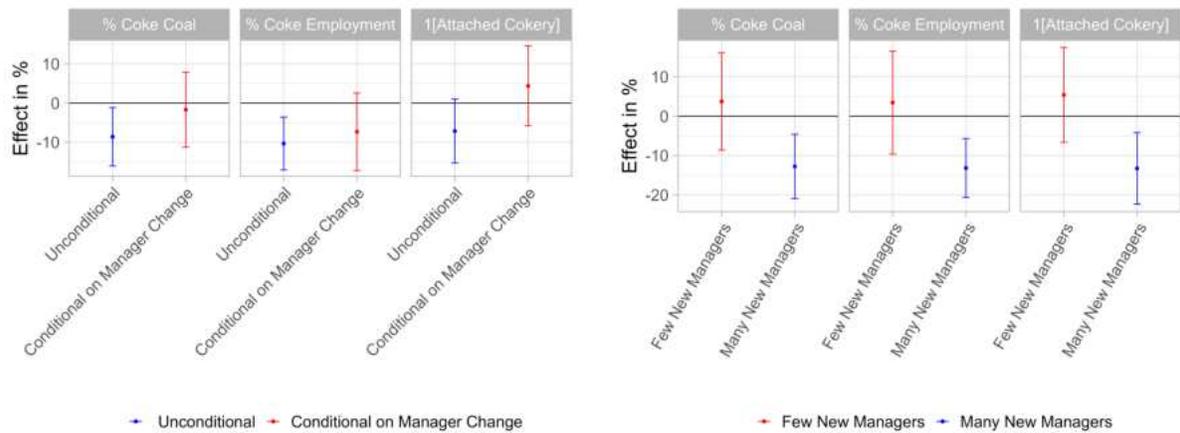
Figure 18: Effect of the *Hüttenvertrag* Policy on Demand Uncertainty: Extensive Margin

Notes: This figure gives the effect of the policy on the likelihood of a positive or very high annual share of cancelled shifts due to insufficient demand.

demand uncertainty significantly compared with non-cokery mines, but not for the counterparts with few new managers hiring. This evidence echos well with what we found in Figures 14 and 18 that high prior-policy demand uncertainty led cokery mines to hire more new managers, and these newly hired managers helped reduce demand uncertainty in both intensive and extensive margins. Meanwhile, the cokery mines with few new managers hired post-policy are those with relatively low prior-policy demand uncertainty already. Hence, we do not find a significant decrease in demand uncertainty for them.

6.2 Technology Adoption

In Section 5.1, we found that cokery mines hired more new managers with STEM backgrounds and from more productive former employers, who tend to have better knowledge about coal mining technology and bring advanced experience in the organization of coal mining. We first check the dynamic effect of the policy on the mechanization rate, as shown in Figure 20. It presents the policy that significantly increased the share of mechanized production by up to 10%. The increase in the mechanization rate was persistent over time and aligns with the productivity surge we observed in Figure 6 post-policy.



A. Intensive Margin

B. Heterogeneity by #Manager Change

Figure 19: Effect of the *Hüttenvertrag* Policy on Demand Uncertainty: Intensive Margin

Notes: This figure gives the effect of the policy (un)conditional on manager hirings. We control for manager hirings by adding a variable that pools the number of post-policy manager hirings in cokery mines at the mine-level. Standard errors are clustered at the cokery level and 90% confidence bands are reported.

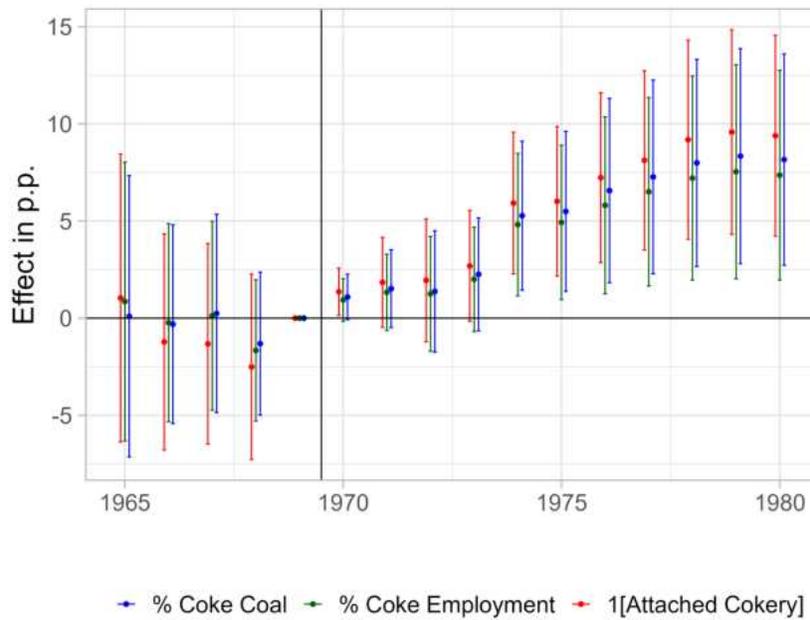


Figure 20: Effect of the *Hüttenvertrag* Policy on Mechanization Rate

Notes: This figure gives the regression results of Eq.(2) with the mechanization rate as an outcome variable. Standard errors are clustered at the mine level and 90% confidence bands are reported.

To specifically examine whether the improved technology adoption of coal mining was attributed to manager changes, we further check the effects of the *Hüttenvertrag* policy on the mechanization rate following the same specification we conducted for examining the intensive margin effect on demand uncertainty. Figure 21 reports the results. Panel A shows that the policy significantly increased the adoption of mechanized technology (blue), and manager change accounted for the driving reason (red). In Panel B, we find that cokery mines that hired more new managers significantly increased their mechanization rate relative to non-cokery mines.

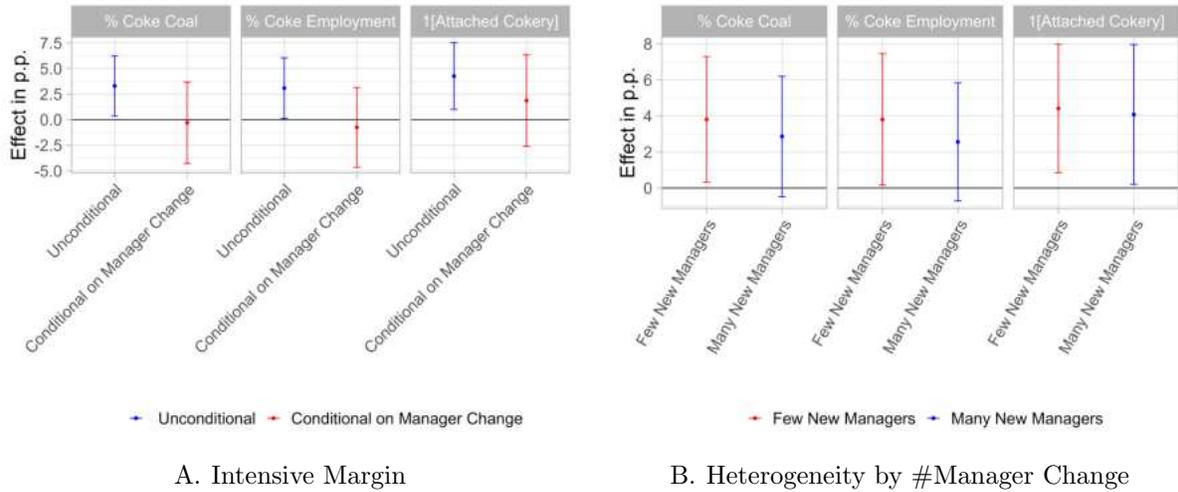


Figure 21: Effect of the *Hüttenvertrag* Policy on Mechanization Rate

Notes: This figure gives the effect of the policy (un)conditional on manager hirings. We control for manager hirings by adding a variable that pools the number of post-policy manager hirings in cokery mines at the mine-level. Standard errors are clustered at the cokery level and 90% confidence bands are reported.

6.3 Cokery Operation

While we looked at the effects of the policy above on coal mine-level outcome variables, we noticed that cokeries could also adjust their organization of production accordingly. See Appendix B for a description of the evolution of aggregate productivity for cokeries. As managers can not only manage coal mines but also affiliated coking plants, we now examine the policy effect on coking plants' efficiency and the role of manager changes.

In Section 5.2, we showed that cokery mines with high prior-policy demand uncertainty hired more new managers in response to the reduced import competition. Therefore, though

the policy treated all coking plants, we compare high prior-policy demand uncertainty cokeries with low prior-policy demand uncertainty counterparts by estimating the equation as follows:

$$Y_{it} = \beta HighDemandUncertainty_i \times Post_t + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (12)$$

where $HighDemandUncertainty_i$ equals 1 if the coal mine that coking plant i affiliated with had an above-median demand uncertainty (measured by the share of canceled shifts due to insufficient demand as in Section 4.2) in the pre-policy years (1960-1969) and 0 otherwise. To examine the policy effect on coking plants' efficiency and the role of manager changes, we further estimate TFPQ for cokeries. We also use two commonly used productivity proxies, i.e., labor productivity (output per worker) and output-input ratio (output per used tonne of coking coal), as robustness checks.

TFPQ Estimation for Cokeries. The TFPQ estimation for cokeries follows a similar approach as the TFPQ estimation for mines, including the same additional variables into the law of motion. We specify a Leontief production function for cokeries. Cokeries produce coke output Q_{it}^C with coking coal as a material input M_{it}^C , employment as labour L_{it}^C , and oven capacity as capital K_{it}^C :

$$Q_{it}^C = \min\{\kappa_{it}M_{it}^C, F^C(L_{it}^C, K_{it}^C, \beta^C)exp(\omega_{it}^C)\}exp(\epsilon_{it}) \quad (13)$$

where $F^C(\cdot)$ is a Cobb-Douglas production function and ω_{it}^C is TFPQ. We assume that coking coal is non-substitutable with labor and ovens since coking coal is the indispensable input for the cokery process. Thus, the Leontief specification implies a fixed-proportion rule in equilibrium between coking coal and other inputs, i.e., $\kappa_{it}M_{it}^C = F^C(L_{it}^C, K_{it}^C, \beta^C)exp(\omega_{it}^C)$, which enables a direct control for unobserved productivity in the follow-up estimation procedure (in logged terms): $\omega_{it}^C = \ln(\kappa_{it}) + m_{it}^C - f^C(l_{it}^C, k_{it}^C, \beta^C)$.

Following De Loecker and Scott (2022), we proxy κ_{it} by a nonparametric function of inputs and other cokery-year-level variables; however, the ratio of input to output is relatively fixed with on average 1 tonne of coking coal translating to 0.276 tonnes of coke (with a standard deviation of 0.010 tonnes of coke). Again, we assume labor to be the flexible input of the

Cobb-Douglas part of the production function. The law of motion is identical to the TFPQ estimation for coal mines as in Eq.(6), including the treatment variables, a vector of dummies for the years relative to a new manager hiring, demand uncertainty, and exit probability in the next period. Finally, we form similar moment conditions as in Eq.(7) without adding material input and use a GMM estimator to identify relevant parameters.

Figure 22 presents the estimation results of Eq.(12). Cokeries that are affiliated with high-demand uncertainty mines significantly increased their TFPQ, labor productivity, and output/input efficiency. Also markups increase and marginal costs decrease. Markups and marginal cost are not significantly affected. The latter are calculated based on the Leontief production function, so that cokery markups are given by $\hat{\mu}_{it}^C = \frac{1}{\frac{\eta_{it}^{LC}}{\beta_{iC}} + \hat{\eta}_{it}^{MC}}$ and cokery marginal costs are given $mc_{it}^C = \frac{P_{it}^C}{\mu_{it}^C}$ (De Loecker and Scott, 2022)¹⁴ Importantly, $\hat{\eta}_{it}^{MC}$, the revenue share of material inputs is an estimate given that it is based on the marginal cost estimate of mine production function.

The reduction in marginal cost and the increase in markup is to a large extent explained by the reduction in marginal costs of coal in the attached mine, given that coal input is the main cost component in cokeries (mean $\hat{\eta}_{it}^{MC} = 0.800$). Controlling for mine-level changes in marginal costs, the point estimate on marginal costs changes from -0.034 to -0.020.

The production of side products of the cokery process, benzole and tar, remained unaffected. This happened while the employment and aggregate coke output of the cokeries were unaffected. These results indicate that the performance of not only the mine per se but also the affiliated cokery increased if its coal mine had high pre-policy demand uncertainty, which is consistent with our previous expectation on the role of management practices that are effective to both mines and affiliated coking plants.

¹⁴This assumes that cokeries minimize costs independent of the vertically integrated upward mine production. The type of capital input and workers needed for both production step (mine and cokery) are different and, hence, input costs for the substitutable inputs capital and labour are not affected by the respective other production step.

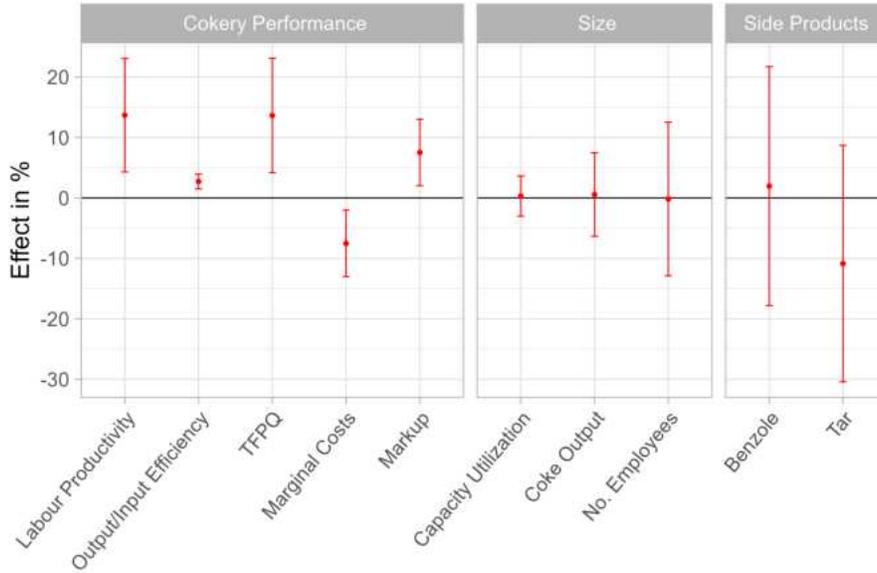


Figure 22: Effect of High Pre-Policy Demand Uncertainty on Cokery-Level Outcomes

Notes: This figure gives the results of a difference-in-differences regression where we compare high- and low-demand uncertainty cokeries before and after the policy conditional on the establishment and year-fixed effects. Standard errors are clustered at the cokery level and 90% confidence bands are reported.

7 Robustness Checks

In this section, we perform several robustness checks and reestimate our analysis with slightly adapted regression specifications to account for potential identification concerns.

Ruhrkohle AG. The *Hüttenvertrag* coincides with another industrial policy in the industry. In 1968, the German government set up the *Ruhrkohle AG*, a quasi-monopolist of the industry, by merging almost thirty independent coal firms. If the merger induced within-firm changes correlating with the exposure measure of the *Hüttenvertrag* beyond the contract itself, we might capture the merger effects in our analysis. However, this is not the case. The main goal of the merger was to secure sufficient sales - independent of which type of mine produced coal (Gatzka, 1990). Instead, the *Hüttenvertrag* was the main and only policy tool of restructuring in the *Ruhrkohle AG* taking into account cokeries.

Furthermore, to show that the effects are not simply caused by the merger and its reallocation effects, we show that our main results also hold within groups of mines that belonged to the same pre-merger firm. Figures A7 and A8 give a number of robustness checks and their es-

timates relative to our baseline models; among them the robustness check for using ex-firm-year fixed effects. It shows that most of the *Hüttenvertrag*-induced productivity and mechanization changes take place within the groups of former firms.

Product Quality. We test whether product quality changes in response to the treatment. In doing so, we rely on explicit quality proxies that directly come from the data: (i) the share of quarried, non-coal output to proxy the purity of coal and (ii) the average calorific value of the produced coal (i.e., the energy content of the quarried coal).¹⁵ We abstract from implicit measures of perceived quality estimated in the production function approach (e.g., [Amiti and Khandelwal, 2013](#); [Khandelwal et al., 2013](#)). These measures compare realized demand with expected, price-adjusted demand, relying on a set of assumptions such as consumer utility functions. Figure [A5](#) shows that the policy affected neither the share of non-coal content quarried nor the average calorific value of quarried coal.

Markdown. To understand whether higher markups are also shared with workers, we estimate the policy’s effect on the mines’ markdowns (e.g., [Delabastita and Rubens, 2023](#); [Rubens, 2023b](#)). Reasonably assuming that mines cannot impact the price for material, i.e., the pitwood price, the markdown for labor, λ_{it} , is proportional to the ratio of material and labor expenditures for a Cobb-Douglas production function: $\lambda_{it} = \frac{\beta^L}{\beta^M} \frac{P_t^M M_{it}}{w_{it} L_{it}}$. Using this insight, we show in Figure [A6](#) that the policy does not significantly impact the labor markdown.

Balanced Sample. To ensure that our results are not purely driven by policy-induced attrition but also by outcome changes within surviving mines, we rerun our analysis in a sample of mines still existing in 1980. Figures [A7](#) and [A8](#) show that our results are robust to this check.

Local Effects. In our baseline results, we compared the policy’s effects in the overall sample of coal mines. In Figure [A7](#) and [A8](#), we include more granular fixed effects, i.e., mining region-year fixed effects for five mining regions. This allows us to compare mines in small local areas with, among others, very similar labor market conditions. The mining regions were defined by the

¹⁵We only calculate the average calorific value based on non-fat coal output as the share of fat coal is a direct outcome of the policy.

Ruhrkohle AG with separate subsidiary chair and management. Figures A7 and A8 show that when comparing mines in small local areas with similar preconditions, the policy has robust effects on mechanization and productivity.

Inference. We rerun our primary analyses using Conley (1999) standard errors to account for spatial correlation in the residuals. This is justified by potential local spillovers of policy exposure, given that all mines are located in a 50x100km area. Our results are unaffected (see Figures A7 and A8).

Mine Mergers. During the period of our analysis, several mines merged coal fields. Minefield mergers might correlate with expectations of the mines' future profitability and potential. We, therefore, test whether controlling for mine-level mergers changes our results. Figures A7 and A8 show this is not the case.

Weighting Scheme. Mines differ in their size, and treatment effects in larger mines might matter disproportionately for labor markets or aggregate production. Hence, we rerun our most important checks by weighting observations by size. In Figures A7 and A8, we show that our results are untouched by the weighting coal mine observations by the pre-policy mine size (i.e., output in 1969).

Short-Run Exposure. In our baseline estimates, we calculate the exposure to the policy based on all pre-policy years. However, the importance of a mine's cokery changes over time, so we run a robustness check with exposure measures calculated only based on the last four pre-policy years. Figures A7 and A8 reveal that our results do not change qualitatively when using the short-run exposure measures.

Alternative Treatment Specification. Our treatment variable in the regressions above relies on the mine-level connection of cokeries to mines. However, mines with no directly linked cokery can also use other mines' cokeries or so-called 'central cokeries' (seven cokeries that pool coal from several mines). Thus, we would likely understate that mines without cokeries are also affected by the policy of non-zero treatment. We, therefore, check the robustness of our

analyses' results based on alternative treatment specifications, taking this into account.

Figure A4 uses treatment allocation based on (i) the pre-policy share of coal output suitable for cokery usage (i.e., the share of fat coal quarried) and (ii) the distance to the nearest mine cokery or central cokery. We show that a higher fat coal production share pre-policy (in 1969) as well as being close to a cokery (i.e., closer than 2.5 or 5km to a cokery in post-policy years) yields very similar results than our baseline approach.¹⁶

8 Conclusion

In this paper, we study the role of management practices as an underlying mechanism to increase coal mines' productivity under reduced import competition due to an industrial policy in the German coal mining industry. Recall the ambiguous theoretical net effects of competition on management practices: either increase due to competitive pressure or decrease because of lower manager pay derived from lower market power. Our empirical findings in the German context show that the channel of high market power leading to better managerial practices and talents dominates the other.

This paper has two important implications beyond the German coal mining industry setting. First, our findings echo current concerns about the return of protectionism (Amiti et al., 2019; Fajgelbaum et al., 2020; Antrás and Chor, 2022; Fajgelbaum et al., 2024), which substantially reduces import competition. We indicate that hiring high-quality managers can offset the negative productive effects by better predicting future demand and promoting technology adoption. Second, high volatility of firm-level demand is associated with firm profitability, size, entry/exit, structure of the industry, market power, and beyond (Guiso and Parigi, 1999; Collard-Wexler, 2013; Asker et al., 2014; Kumar and Zhang, 2019; Jiang and Zhang, 2024). This paper shows that an industrial policy targeting reducing demand uncertainty could be effective in boosting firm performance.

¹⁶The median distance to a cokery for mines with non-linked cokeries is 5.5km.

Appendix

A Figures

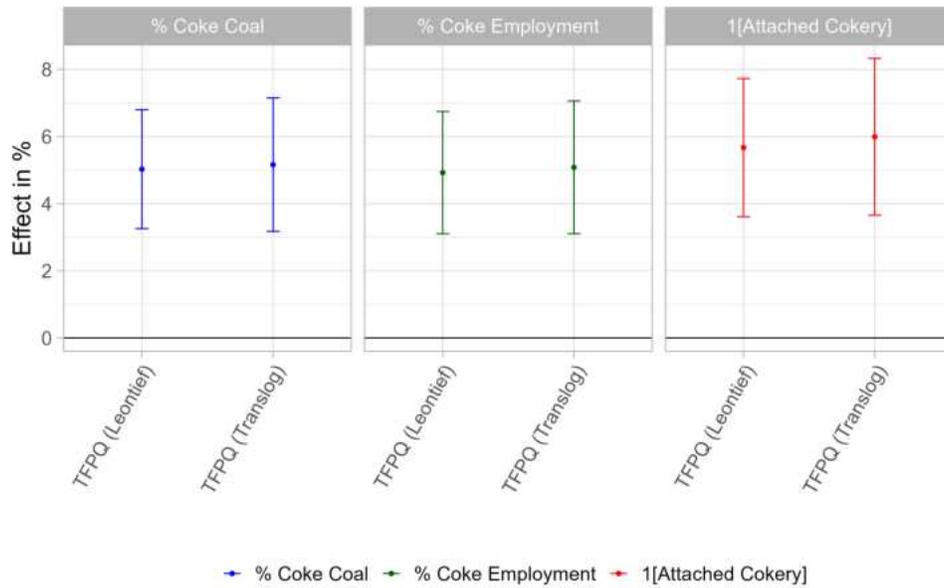


Figure A1: Effect of the *Hüttenvertrag* Policy on TFPQ - Robustness Checks

Notes: This figure gives the regression results of Eq.(2) with TFPQ based on different production functions as outcomes. Standard errors are clustered at the mine level and 90% confidence bands are reported.

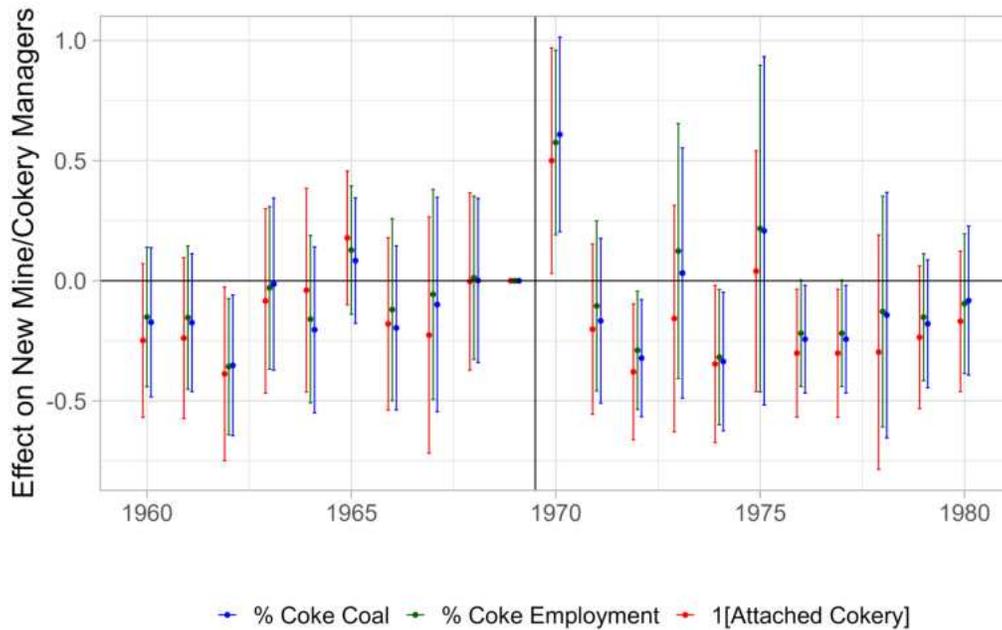


Figure A2: Effect of the *Hüttenvertrag* Policy on the Number of Newly Hired Mine/Cokery Managers

Notes: This figure gives the regression results of Eq.(2) with the number of newly hired managers as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

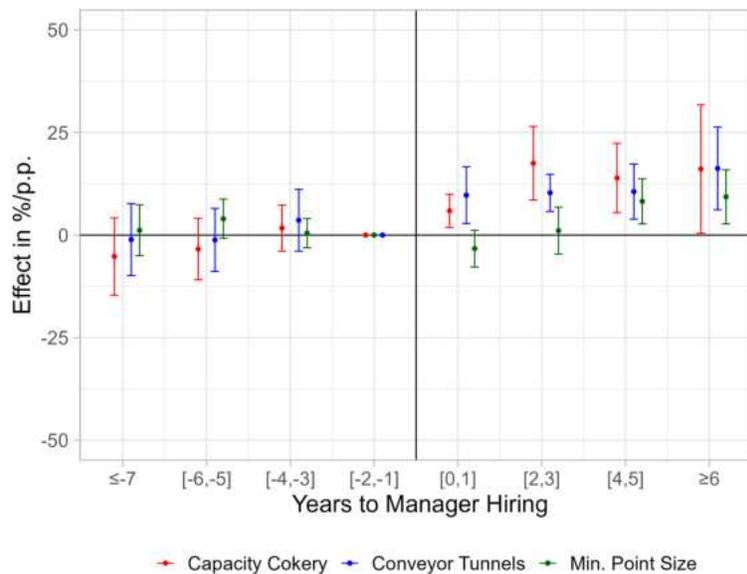


Figure A3: Effect of Manager Hiring on Mine-Level Investments

Notes: This figure gives the regression results of an event study regression on various outcomes; with a manager hiring event in a mine with positive exposure post-policy being the treatment. Standard errors are clustered at the mine level and 90% confidence bands are reported.

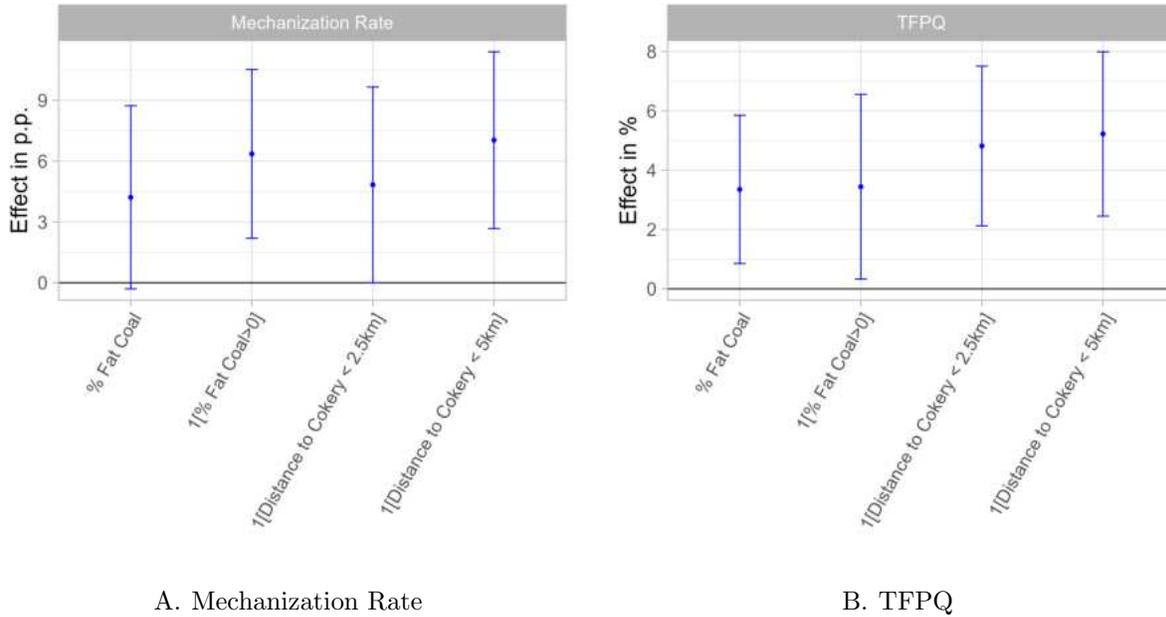


Figure A4: Effect of the *Hüttenvertrag* Policy on Mechanization and TFPQ - fat coal and cokery exposure

Notes: This figure gives the regression results of Eq.(2) with the share of mechanized production and total factor productivity as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

B The Evolution of Aggregate Productivity for Cokeries

We provide insights on two aggregate productivity proxies below in Figure A1. We look at labor productivity, i.e., labor productivity (output per worker), and output-input ratio (output per used tonne of coking coal), for cokeries. Cokeries have three outputs (coking coal, benzole, and tar), of which coking coal is the main product, and benzole and tar are side products. Panel A shows that cokeries, if at all, produce slightly more from a tonne of coking coal after 1970. However, there is a declining efficiency for benzole and tar. For labor productivity, we find a substantial increase for all products until the policy in 1969. Afterward, labor productivity remains relatively stable.

In Figure A2, we further show that cokery attributes change over time in our sample. While cokery utilization (i.e., production as a share of capacity) has remained constant at around 80%, the average cokery increased its capacity and the average cokery oven size substantially.

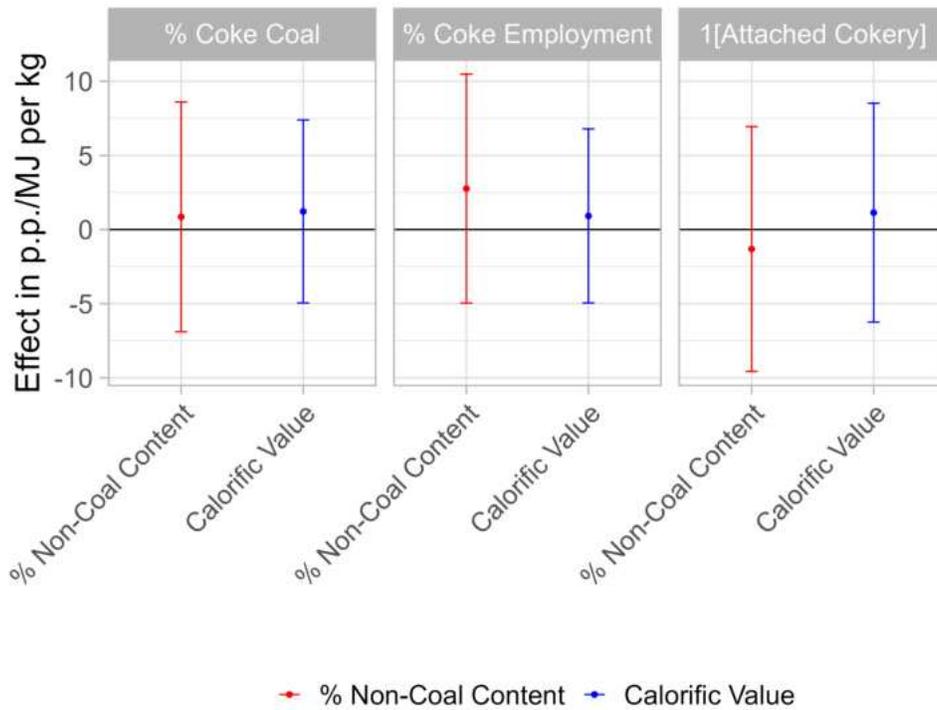


Figure A5: Effect of the *Hüttenvertrag* Policy on Product Quality

Notes: This figure gives the regression results of Eq.(2) with quality proxies as outcomes. Standard errors are clustered at the mine level and 90% confidence bands are reported.

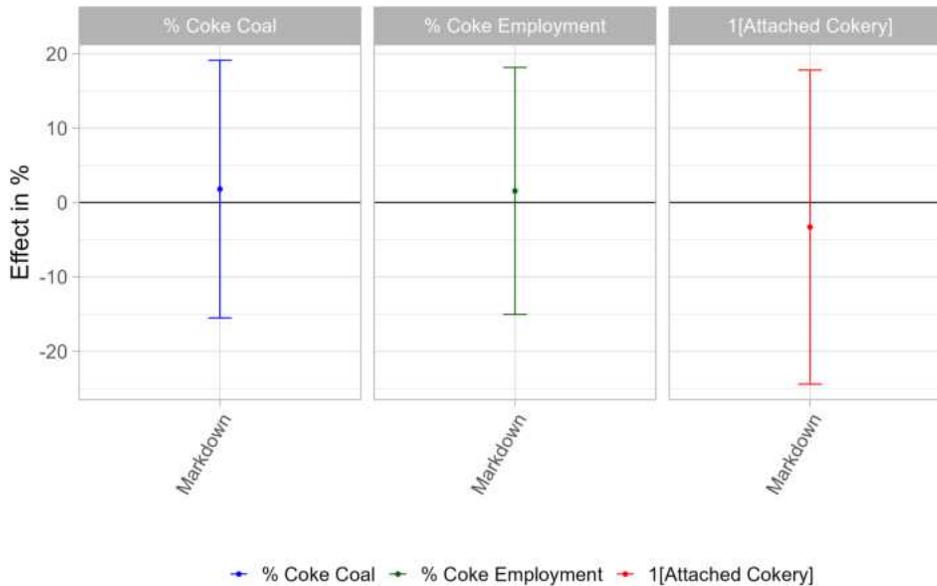


Figure A6: Effect of the *Hüttenvertrag* Policy on Markdown

Notes: This figure gives the regression results of Eq.(2) with the estimated markdown as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

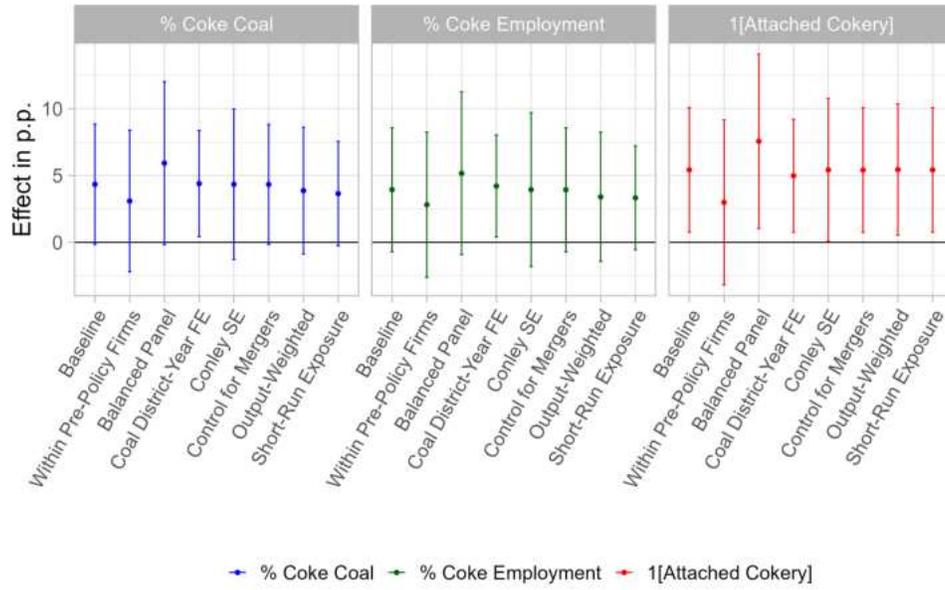


Figure A7: Effect of the *Hüttenvertrag* Policy on Mechanization - Various Robustness Checks

Notes: This figure gives the regression results of Eq.(2) with the share of mechanized production as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.

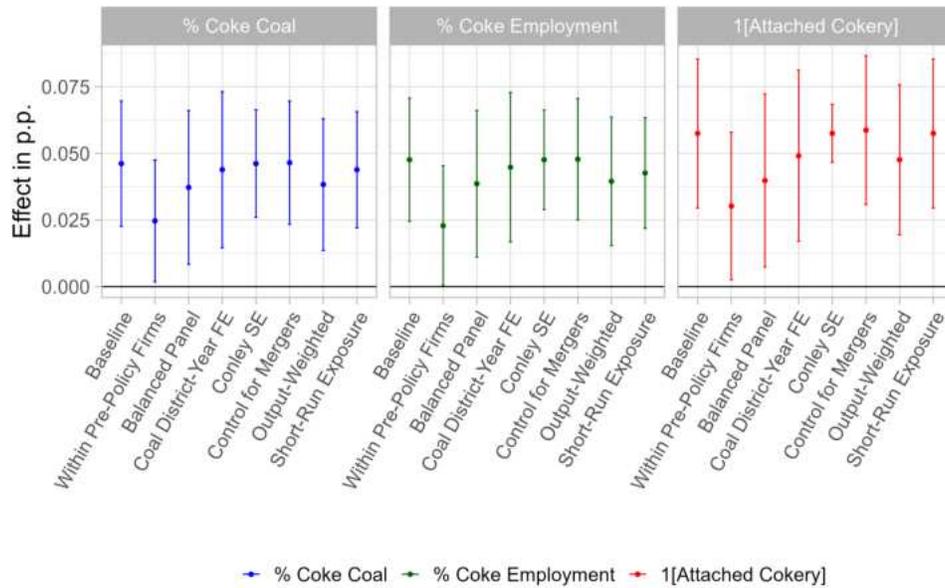
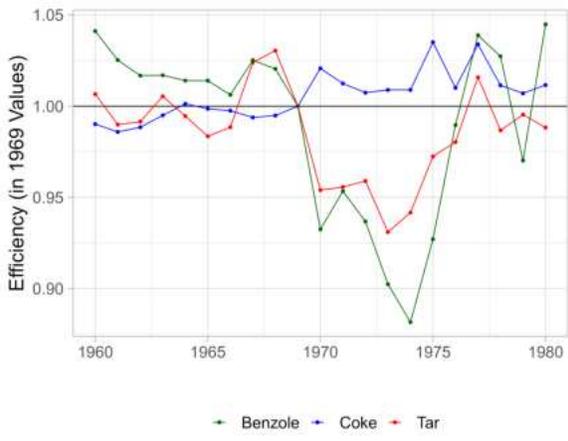
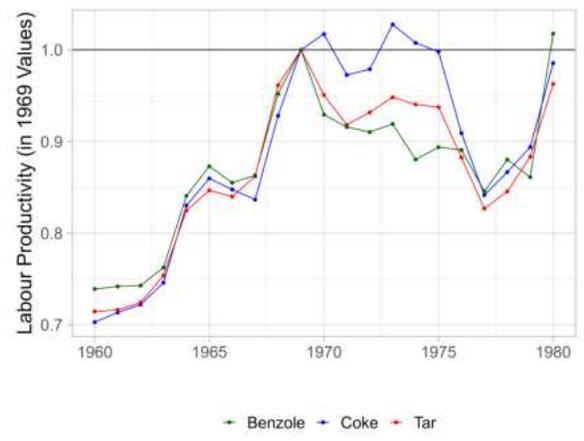


Figure A8: Effect of the *Hüttenvertrag* Policy on TFPQ - Various Robustness Checks

Notes: This figure gives the regression results of Eq.(2) with total factor productivity as an outcome. Standard errors are clustered at the mine level and 90% confidence bands are reported.



A. Output-Input Ratio (Efficiency)



B. labor Productivity

Figure A1: Productivity Proxies for Cokeries over Time

Notes: This figure gives the weighted average of cokery productivity proxies over time. First, the output-input ratio and, second, the labor productivity by type of cokery product is given.

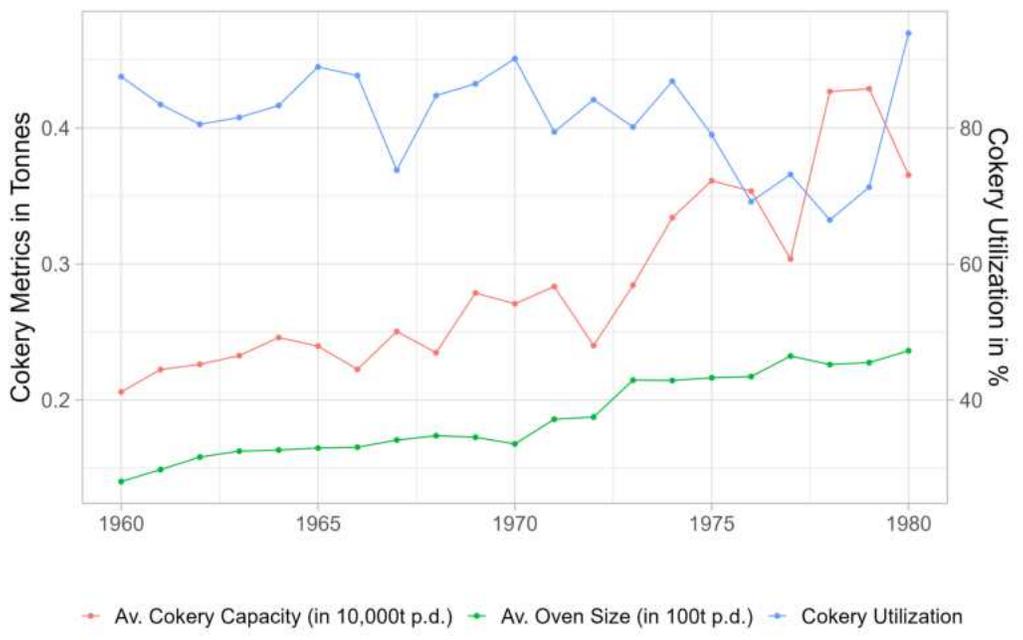


Figure A2: Cokery Attributes over Time

Notes: This figure gives information on the average cokery in the sample over time.

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