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RESEARCH ARTICLE



Lessons from Germany's hard coal mining phase-out: policies and transition from 1950 to 2018

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ABSTRACT

German hard coal production ended in 2018, following the termination of subsidies. This paper looks at 60 years of continuous decline of an industry that employed more than 600,000 people, through a case study comparing Germany's two largest hard coal mining areas (Ruhr area and Saarland). Although predominantly economic drivers underlay the transitions, both provide valuable lessons for upcoming coal phase-outs induced by stricter climate policies, including beyond Germany.

The analysis identifies the main qualitative and quantitative characteristics of the two regions. It then discusses policy instruments implemented to guide the transition, including measures for the conservation of coal production, regional economic reorientation, and the easing of the transition's social impacts. The success of these policies is evaluated using economic, social, and geographical indicators that were developed within three interdisciplinary research projects running from 2016 to 2019.

A key lesson from the examined case studies is the importance of combining not only policies addressing unemployment and the attraction of new energy corporations and investments, but also measures improving infrastructure, education, research facilities and soft location factors. Protecting a declining industry for decades caused increased transition costs compared to an earlier phase-out. Economic reorientation and changing regional identities have proven most difficult in the past. However, the German example illustrates that the complexity of the challenges of a transition can be mastered if city, regional, and national governments and institutions cooperate in a polycentric approach.

Key policy insights



- A faster and more pro-active hard coal mining phase-out in Germany would have been much less expensive and paved the way for new industries
- A *just and in-time transition* needs to:
 - be jointly managed in a polycentric approach by city, regional, national, and international governments and institutions.
 - combine climate, energy, social, and structural policies, whilst recognizing both local specifics and global connections.
 - consider long-term effects, external independent advice apart from the incumbent regime and beyond-border thinking, while aiming to diversify the economy and enabling broad stakeholder participation.
 - address unemployment, the economy, and the energy system, as well as measures to improve infrastructure, universities, research facilities, and soft location factors.


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1. Introduction

Through the 2015 Paris Agreement, the world community committed to keeping global temperature rise ‘well below’ 2°C compared to preindustrial levels (UNFCCC, 2015). In response, in 2017, at the Bonn Climate Conference, the ‘Powering Past Coal Alliance’ (PPCA) was founded, pledging to end unabated coal consumption in OECD countries by 2030 at the latest (PPCA, 2017). By mid-2019, 32 countries and 59 sub-national governments or businesses had joined the alliance (PPCA, 2019). In 2019, a stakeholder commission on ‘growth, structural change and employment’ (in the following called ‘Coal Commission’) installed by the German government recommended a coal phase-out by 2035–2038 (BMW, 2019). Germany joined the PPCA at the UN Climate Action Summit held in New York in September 2019, when its membership structure was changed to allow countries that have set a later phase-out date to join (BMU, 2019), Germany, however, remains ineligible to join the inner PPCA Declaration Group, which is restricted to OECD members with a coal phase-out date of 2030 at the latest (and 2050 for non-OECD members).

Despite previously being seen as an ambitious country in climate protection, mainly because of its 2000 ‘Renewable Energy Act’ (German: ‘EEG’), Germany has played an ambiguous role in international efforts to combat climate change due to its active coal mines and large coal-fired power plant fleet (Hirschhausen, Gerbaulet, Kemfert, Lorenz, & Oei, 2018). Final legislation on a coal phase-out is still pending, while a transition in line with international climate commitments would call for an earlier phase-out by 2030 (Göke, Kittel, Kemfert, Oei, & von Hirschhausen, 2018; Parra et al., 2018). As the ongoing debate around and within the Coal Commission shows, key challenges include possible disruptive effects of a phase-out for the energy system as well as the social consequences for coal industry workers and related regions. Thus, the inclusion of regional aspects of social and structural policy into the phase-out of fossil fuels is a necessity for addressing (mostly local) resistance (Brauers et al., 2018; Leipprand & Flachsland, 2018; Sartor, 2018).

This resistance originates mostly from the injustice felt by people from the affected regions, especially by workers who fear disadvantages and losses from the shift away from fossil fuels (OECD, 2019). Incorporating both structural policy and climate dimensions is an important aspect of the so called ‘just transition’ concept, specifically targeting the prospects of workers and their families (Rosemberg, 2010). The concept originates from the trade union movement, which highlighted in a statement at the 2007 Bali Climate Conference that

(t)he effects on the economy – including on employment – will be catastrophic if ambitious measures are not taken to reduce GHG [greenhouse gas] emissions. While employment protection has often been used by certain developed country governments as a reason for not engaging in GHG emissions reductions, emerging evidence indicates that climate change mitigation has positive net employment effects. (ITUC, 2007, p. 4)

The importance of the concept to facilitate consensus-building over the transition away from fossil fuels was highlighted further by the ‘Solidarity and Just Transition Silesia Declaration’ issued at the 2018 Katowice Climate Conference (UNFCCC, 2018).

However, the far-reaching consequences of the consumption of fossil fuels call for a wider conception of justice beyond the concerns of (mining) workers at the regional level. While the International Labour Organization’s concept of a ‘just transition’ focuses on securing jobs and alleviating local social problems, other concepts, e.g. environmental justice, energy justice, climate justice, and intergenerational justice, take a more global and holistic perspective, also including non-humans as subjects of justice. Under such a perspective, a faster end to fossil fuel use becomes paramount. All these concepts have in common the promotion of a transition from an extractive fossil fuel-based economy to a less consuming, renewable fueled society.¹

Bringing these different concepts together, Heffron and McCauley (2018) propose subsuming energy, environmental, and climate justice under a redefinition of the original term ‘just transition’. We follow this approach and, because we want to stress not just the need for a socially well-managed transition, but also the urgency of a speedy transition in line with climate protection commitments, we refer to the term ‘*just and in-time transition*’ used by the German Advisory Council on Global Change (in German, WBGU) (2018).

A well-designed energy transition can have positive side-effects on other UN sustainable development goals (2016), including social aspects (Fuso Nerini et al., 2018; McCollum et al., 2018). Within the existing literature, however, until now, climate or structural policy aspects have mostly been analyzed separately. The literature

on climate policies thus differentiates between supply-side policies targeting the extraction of fossil fuels (van Asselt & Lazarus, 2018; Green & Denniss, 2018), and demand-side policies that provide indirect incentives to reduce fossil fuel consumption (e.g. Fais, Blesl, Fahl, and Voß (2015) on Germany). Most of these papers focus on experiences and literature directly linked to climate policies. This neglects findings from additional case studies of past economically-induced structural processes.

Initially, most academic studies on the fossil fuel phase-out process focused on the affected workers, with the environmental aspects of coal only taken into account subsequently. The literature on the German coal phase-out therefore deals with the decline of coal use (Lerch, 2007; Nonn, 2009), the roles of the relevant stakeholders in this process (Renn & Marshall, 2016; Weber & Cabras, 2017), and the impact of the changed situation in the mining regions on their spatial and economic development (Giersch, 2007; Schulz & Dörrenbächer, 2007). Some studies link the historical development of the coal regions with the current situation, deriving political recommendations for action (Arndt et al., 2015; Bogumil, Heinze, Lehner, & Strohmeier, 2012; Goch, 2017). Other scholars investigate past coal transitions in other countries (Caldecott, Sartor, & Spencer, 2017). Within this literature, the justice concept is limited to the effects in the coal regions, with little to no connection to climate justice, or the effects of climate change on other regions. With this case study, we combine these strands of literature, simultaneously looking at climate and structural policy regulation in Germany, as well as the resulting effects for the regional economies. Additionally, the paper highlights the justice implications of the German coal transition, which need to play a role in planning processes of upcoming energy transitions.

Throughout the twentieth century, most political measures to ease the transition in Germany were aimed at solving (local) economic, social and, to a lesser extent, environmental problems in the mining regions. Switching electricity production for climate reasons did not play a significant role. Consequently, when hard coal mining in Germany became too costly, it did not lead to a reduction in coal consumption, rather most coal-fired power plants switched from domestic to cheaper imported hard coal (mostly from Colombia, Russia, the USA, and South Africa). Additional environmental regulation concentrated on improving water and air quality as well as recultivation of past mining sites, but did not seek to reduce the use of coal power plants. Germany implemented additional climate political instruments, such as the Renewable Energy Act, one of the essential drivers for the (international) success of renewables (Egerer, Oei, & Lorenz, 2018). The uptake of renewables at the beginning of the twenty-first century, however, mostly replaced the shrinking share of nuclear energy, while coal consumption stayed relatively constant until 2018 (Oei, 2018).

The (predominantly) economically induced German hard coal phase-out since the 1950s is, therefore, a valuable case study for examining the reduction of coal supply (mining) while excluding coal demand (power plants). Long-term successes and shortcomings can be identified, thus providing valuable lessons for energy transition research. The analysis provides lessons not just for other countries, including Colombia and South Africa, where coal mines are likely to close in the future (Oei & Mendelevitch, 2019; Sartor, 2018; Spencer et al., 2018), but also Germany, where the remaining lignite mines will be phased-out within the next 20 years (Stognief, Walk, Schöttker, & Oei, 2019).




1.1. Research aim and methodology

Germany delegates a significant number of political competencies to each constituent federal state. This provides the opportunity to examine different case studies of coal regions, each with their own set of policies and developments over a similar time period, given comparable institutional settings. In our explorative study, we analyze and compare two hard coal regions, namely Ruhr and Saarland, each located in a different federal state, thus facilitating the detection of factors contributing to the effect of transition policies (section 2). The data stem from available statistical information about the regional economy and industry, a review of the extensive academic and grey literature on the German coal industry,² and observation visits to the regions including informal background discussions with (mainly local) stakeholders comprising individuals representing government, industry, civil society, and academia. The research was performed over the 2016–2019 period, and conducted within the context of three separate but overlapping research projects.³

This paper evaluates policy measures implemented in the two largest German hard coal mining areas in the context of the phase-out of hard coal production between 1950 and 2018, to derive lessons for future

phase-out pathways, motivated by climate policy concerns. Economic, social, and geographical indicators and properties of both regions are used to enable a better evaluation of the success of the implemented measures. The choice of indicators (displayed in Table 1), as well as their interpretations, are based on findings of four inter – and transdisciplinary workshops held in 2017 and 2018. The workshops' participants were representatives of local governments, industry, and academia involved in structural policies, or who had a climate and energy policy background. Findings were derived by combining results from the relevant literature and actual socio-economic indicators, as well as the evaluation of impacts for affected regions by the aforementioned experts. Intermediate results were verified by presentations at a hearing in front of the German Coal Commission and at seven national and international energy or climate policy conferences. Thereafter, these were finalized using direct feedback from local representatives of the affected areas. At this

Table 1. Characteristics of the Ruhr area and Saarland.

		Ruhr area	Saarland
Main characteristics of the region			
Size		4,400 km ²	2,600 km ²
Location		Close to the border with the Netherlands	At the border with Luxembourg and France
Population	1961	5,674,223	1,083,012
	Min	5,045,784 (2013)	989,035 (2014)
	Max	5,756,623 (1965)	1,132,127 (1966)
	2017	5,113,487	994,187
Population density (2017)		1,150/km ²	380/km ²
Integration to Federal Republic Germany		From the beginning in 1949	1957
Political/Spatial level		Loose regional conglomerate of cities	Federal state
Regional competition		Several, similarly large cities within close vicinity compete with each other and create (inefficient) redundant structures	Concentration on few cities
Political/administrative representation		Organized as a regional entity within NRW with only limited responsibilities	Own federal government
Overall economy within the region			
GDP (per capita) in million €	1991	102,340 (p.c.: 44,444)	21,269 (p.c.: 40,055)
(real)	2016	160,150 (p.c.: 66,924)	34,602 (p.c.: 59,346)
Homogeneity of GDP in region		In the 1990s strong differences, recently weaker cities were able to catch up	Higher GDP/capita in the cities compared to rural area
Gross value added in mill. €	Agriculture,	2,846 (0.4%)	62 (0.2%)
2018 (share of total regional GDP)⁹	Forestation,		
	Fishing		
	Production	178,365 (25.3%)	11,066 (30.8%)
	industry		
	Services	454,554 (64.5%)	21,298 (59.2%)
Mining specifications including employment			
Main energy carrier		Hard coal	Hard coal
Type of mining		Deep mines	Deep mines
Number of mines in 1957		138	17
Employees	1957	~600,000	~65,000
	1967	~290,000	~32,500
	1977	~190,000	~22,000
	2017	~4,500	~139
Ownership		Private	Public
End of operation		2018	2012

Source: Own illustration based on Source: Own illustration based on (Bogumil et al., 2012; Destatis, 2019; Regionalverband Ruhr, 2019; Statistik der Kohlenwirtschaft e.V., 2018; Statistisches Amt Saarland, 2019; VGRdL, 2018).

time, only a few systematic approaches evaluating transition policies exist (for an exception, see Green and Gambhir (2019)). Thus, the transition policies and their outcomes are evaluated according to the typology framework provided by Green and Gambhir (2019) and Spencer et al. (2018). Section 3 derives the most important elements to enable a *just and in-time transition* through an inductive approach from the implemented measures described in more detail in the respective historic phase-out pathways, which are found in the supplementary material. The fourth section concludes, providing limitations as well as lessons learned, which can be used for other transition processes in Germany or other regions of the world.

2. Lessons from phasing-out hard coal mining in Germany

2.1. Hard coal mining in Germany from 1950 until 2018

Following the Second World War, hard coal was of historic significance for West Germany, forming the cornerstone of its economic, social, and political reconstruction. In 1951, coal provided the possibility to reintegrate into international affairs in the form of the European Coal and Steel Community (ECSC), the predecessor of the European Union. The number of direct jobs within the hard coal mining industry peaked at around 600,000 in 1957, with even more people employed by indirect job opportunities. Its production took place in four underground mining areas, of which the Ruhr area was the largest (up to 123 million t/year) and the Saarland the second largest (up to 16 million t/year).

Due to the extensive production of hard coal and the down-stream steel industry, the Ruhr area developed into the backbone of West Germany. It comprises several large cities in close vicinity within the federal state of North-Rhine Westphalia, forming the densest populated area in Germany. The Saarland, on the other hand, is itself a federal state that reunified with Germany in 1957 (after having been part of France (1920-1935) and then independent (1947-1957)). It is comparatively sparsely populated and forms the second smallest federal state in terms of population. Hence, the history, identity, economic and social characteristics, and even legal representation at the political level vary between the analyzed regions, affecting their coal phase-out pathways (see Table 1).

From 1958 onwards, hard coal production and employment started declining quickly due to a price drop that resulted from the liberalization of coal prices previously regulated by the ECSC (see Figure 1). Domestic coal had

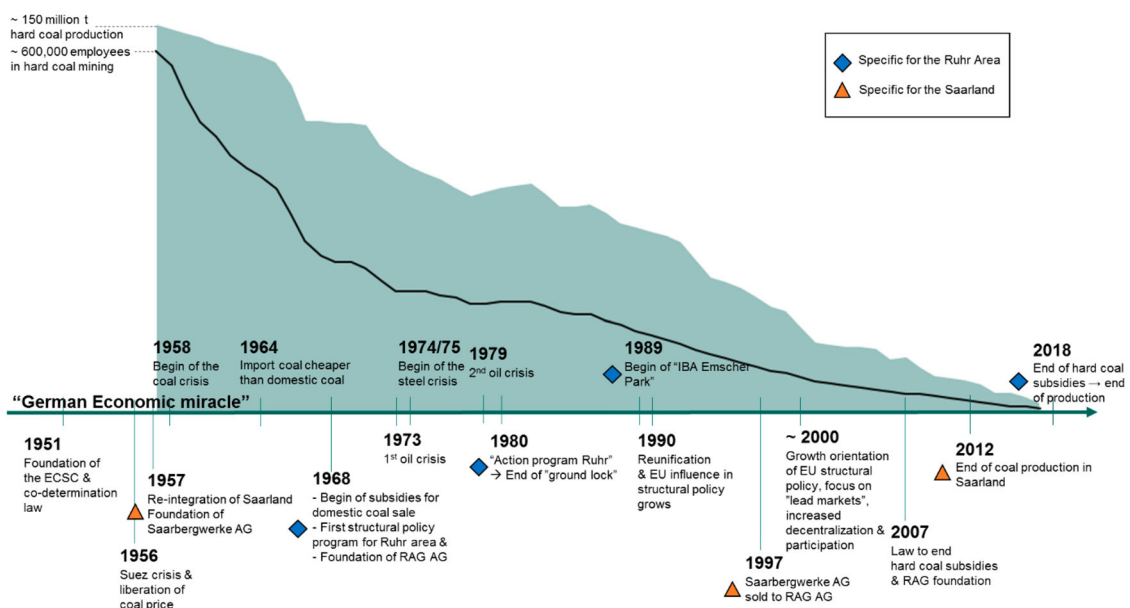


Figure 1. History of hard coal production in Germany and structural policy programs in the Ruhr area and Saarland from 1951-2018. Source: Own depiction based on Herpich, Brauers, and Oei (2018).

to compete with the comparatively cheaper coal from overseas and imported oil, which increasingly substituted hard coal in the heating sector. At the beginning of this coal crisis, economic circumstances in Germany allowed a majority of the former miners to transfer to the metal industries in the regions (Nonn, 2001). For the remaining workers, alternatives like early retirement and retraining were offered and, hence, unemployment rates were kept relatively low (see Figure 2). Throughout the entire phase-out process, none of the mining workers became unemployed and all the decisions were agreed upon with the miners. This was possibly due to the co-determination law⁴ introduced in 1951. However, it only covered the coal and steel sectors, not the down – or upstream industries. These latter industries were affected by the coal and steel crises, resulting in unemployment rates exceeding 15% (see Figure 2).

Consequently, both regions tried to diversify their economies. The first structural programs sought to improve the connectivity of mining regions with neighboring cities (Bogumil et al., 2012). This meant, among other factors, investments in modern transport infrastructure to increase citizens' mobility, thus not only enabling former coal miners to travel between their homes and potential new workplaces outside the mining industry, but also increasing the attractiveness of the region for new enterprises (Goch, 2009).

As depicted in Figure 2, the unemployment rates in both coal regions, as well as the rest of Germany, were strongly affected by the first and second oil crises in 1973 and 1979, as well as reunification in 1990. The unemployment rate of the Saarland remained below that of the Ruhr. In the 1980s and 1990s, structural policy programs focused more on ecological and cultural aspects, increasing entrepreneurial activity in the Ruhr area (Goch, 2009; Hospers, 2004). These efforts helped to slowly change the image of the Ruhr beyond a polluted industrial area (Rimkus, 2007). The share of people working in the secondary sector decreased from 58% in 1976 to 26% in 2014, whereas the share in the tertiary sector increased from 42% to 74%.⁵ Like the Ruhr area, the Saarland shifted toward the tertiary sector. Increased outsourcing of services within firms previously integrated into the industrial sector strengthened this shift (Lerch & Simon, 2011).

It was only in 2007 that the growing influence of the EU forced Germany to end subsidies for hard coal production, which had reached – along with other privileges – between €289 and €331 billion between 1950 and 2008⁶ (Meyer, Küchle, & Hölzinger, 2010). Saarland closed its last mines in 2012, also due to growing safety concerns caused by mining related earthquakes in the region (Hartmann, 2018). The last mines in the Ruhr region were closed in 2018. Research institutes, including the Leibniz-Institute for Economic Research and University Duisburg-Essen, recommended a phase-out by 2012 in order to avoid €4-10 billion in mining damages and

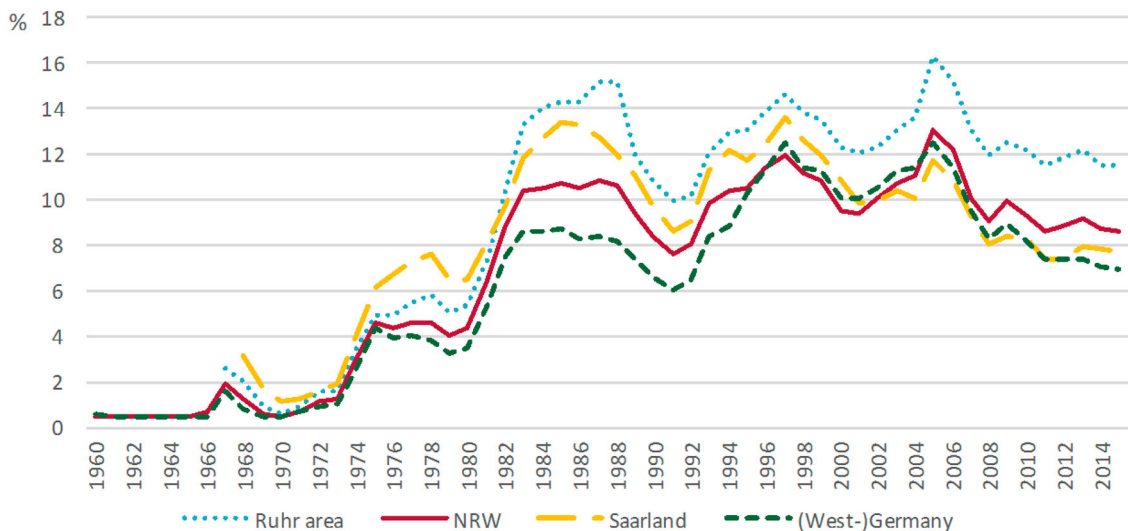


Figure 2. Trends in unemployment rates in the Ruhr area, North Rhine-Westphalia, Saarland and (West) Germany from 1960 to 2015. Source: Regionalverband Ruhr (2017c), Bundesagentur für Arbeit (2018).

Note: The depicted (West-) Germany values are only for West Germany from 1960 until 1990 and from then onwards for the reunified Germany; data for the Ruhr area was available only for the years after 1966, the same accounts for Saarland after 1967.

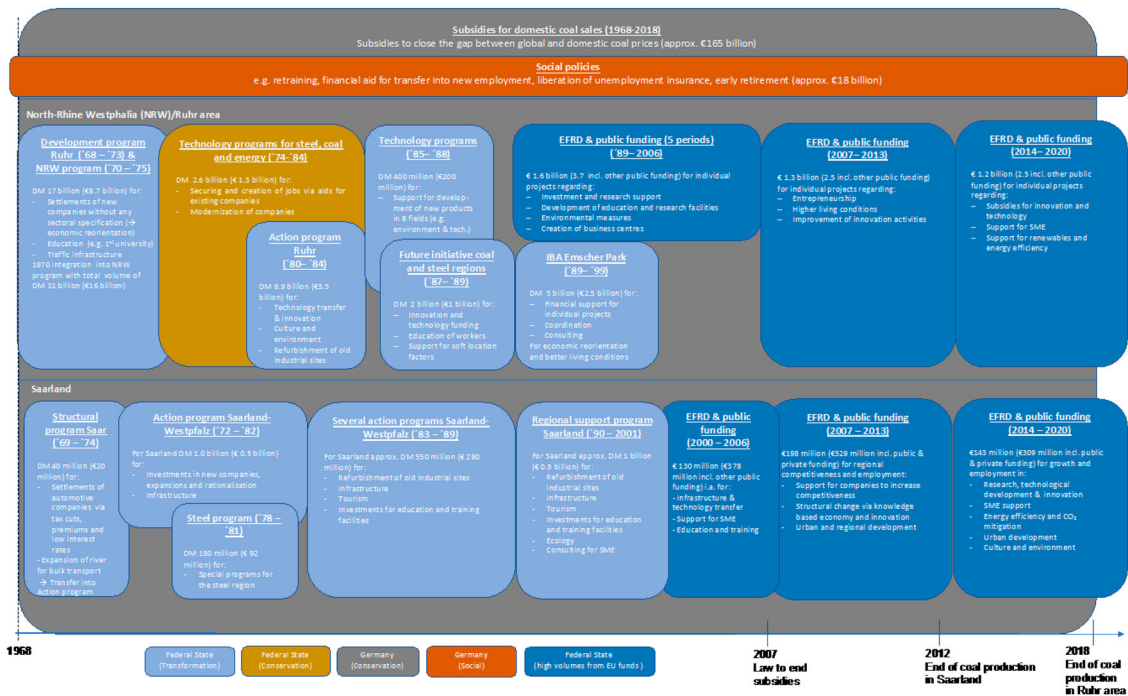


Figure 3. Summary of implemented measures and instruments for the Ruhr area and Saarland during transition. Source: Own depiction, based on (Hartmann, 2018; Goch, 2009, 2011, 2017; Land Saarland, 2014; Untiedt, Ridder, Meyer, & Biermann 2010; Meyer et al., 2010; Anderson, 2007; Fläschner & Hunsicker, 2007; Storchmann, 2005; Bundesregierung, 1983, 1984, 1985, 1990, 1993, 1997; Nägele, 1996).

subsidies (Frigelj, 2009). Alternatively, using these funds to reeducate the remaining employees would have been equivalent to almost €1 million per worker (Frigelj, 2009). The German parliament estimated the total costs for the phase-out period from 2006 to 2018 at around €38 billion, with an additional €2 billion for upcoming pensions and mining damages, and €7 billion for so-called long-term eternity costs that must be paid by future generations (Bundesregierung, 2007; Frigelj, 2009). An overview of the implemented measures and instruments in the transition process beginning with the first transition policy in the Ruhr area in 1968 is shown in Figure 3. Measures that did not aim at a transition, but instead to modernize and therefore conserve the existing mining structures, are marked as such.

2.2. Experiences from the transition in the Ruhr and Saarland regions

The different underlying characteristics of the two regions (see Table 1) complicate a direct comparison of the two phase-out pathways experienced. The transition in the Ruhr area involved a much larger number of workers and mines than in the Saarland. In addition, public ownership granted the Saarland's government important influence over the transformation process. This section focuses on lessons that are of value for future transitions.

An important distinction between the Ruhr area and the Saarland was the differing ability to undergo an economic reorientation. In the Ruhr area, the intended economic diversification, by attracting new companies to the area, was substantially slowed by the joint resistance of mining companies, politicians, and unions (Campbell & Coenen, 2017). This resistance involved institutional lock-in (network of companies, politicians, and unions), economic lock-in (high dependency on the mining and steel industry), as well as cognitive lock-in (the belief that the crisis was cyclical, not structural), leading to persistent attempts to modernize the old structures of the Ruhr area instead of turning to new economic possibilities (Goch, 2009; Hospers, 2004). Consequently, mining companies refused to sell the land they owned to new companies out of the fear that

salaries would rise and employees would switch allegiances, working for new competitors (Der Spiegel, 1960; Michaels, 1960).

In the Saarland, this so-called 'ground lock' was not so much of an issue, partly because of the greater influence of the state and federal government over the mining company due to its public ownership (74% federal, 26% state) and a less densely populated area. The Saarland's government implemented measures incentivizing the mining companies to offer their land and real estate to other companies. Thus, the Saarland profited from the settlement and expansion of suppliers in the automotive industry, including the Ford Motor Company, due to increasing car ownership in the 1960s and 1970s (Fläschner & Hunsicker, 2007; Giersch, 2007). The Saarland's favorable location, close to car manufacturers in Southern Germany, facilitated this transformation.




However, the Saarland was only able to attract companies at a large scale within a small window of time in the 1960s and 70s (Dörrenbächer, Bierbrauer, & Brücher, 1988). Between 1960 and 1970, around 170 companies settled in the Saarland, creating 25,000 jobs. Along with the already present companies, approximately 40,000 coal mining jobs were replaced in this decade (Anderson, 2007). Around 1970, only 4,000 former miners were still unemployed (Lerch, 2007). This shows that an important goal of structural policies is not necessarily to create new industries but to attract new emerging industries and other employers to choose specific regions as places to run businesses. Furthermore, these case studies highlight that economic reorientation worked better when new projects were related to the existing industries in the cities of the mining and steel regions. Regional economic policies in the Saarland were successful because the automotive industry and its suppliers were specifically seeking a workforce with a similar skillset (Giersch, 2007). On the other hand, large projects from distant, unfamiliar sectors proved less successful. For example, the settlement of Nokia in the Ruhr area in 1988 did not involve a sufficient number of local suppliers and networks, and the company left the region for Romania in 2008 following the expansion of the EU (Engel, Neumann, & Schmidt, 2008; Stettes, 2008).

However, this transition from coal and steel toward the automotive industry guided the Saarland into a new dependency. The newly settled companies operate globally and strategic decisions are not made in the Saarland region. Local education and research facilities have only limited possibilities for R&D cooperation and, hence, for labor market relevant developments (Lerch & Simon, 2011). Furthermore, Saarland's industry relies strongly on the export of goods and, thus, depends on the global economic situation (Lerch & Simon, 2011). In 2016, the automotive industry in Saarland achieved a revenue of €10 billion which equaled 38% of the industrial sector and employed more than every tenth worker (Arbeitskammer des Saarlandes, 2017; Bundesagentur für Arbeit, 2019). By relying on the automotive industry for job and income creation, the Saarland is again dependent on the production of a single, large industry.

At the end of the 1990s, the Saarland followed a new path, establishing research facilities connected to information technology (IT), bio- & nanotechnology, as well as medicine in order to develop an innovation-intense and growth-oriented economy (Lerch, 2007). Only the IT research facilities substantially affected the labor market. The main reasons for the limited success in creating employment in other sectors was the limited independence or responsibilities of these subsidiary companies of globally operating corporations (Lerch & Simon, 2011). Thus, the potential for cooperation between research and production leading to the development of new products was limited (Lerch, 2007; Otto & Schanne, 2006).

The transition in the Ruhr area proved to be more complicated, especially for the more northern areas. With its fully exploited coal mines, the southern areas were the first to phase-out mining, therefore profiting as first movers from direct subsidies, new ideas, and the first university. Observing fewer success stories compared to the Saarland, the structural policies in the Ruhr shifted after the 1980s toward a more inclusive approach, supporting promising 'lead markets' and demanding more polycentric coordination of various governmental levels. As a result, subsidies and support schemes were spread widely across industries and sectors increasing the diversification of the region. In the 2010s, within the Ruhr area, cities became increasingly independent, empowered to create their own development strategies reflecting their individual strengths and needs. The city of Dortmund has, for example, constructed a technology center, successfully specializing in microsystem technologies, using synergies from research and innovative companies. However, such fragmentation can also result in duplicative industries and projects, preventing further growth and limiting the exploitation of the region's economic potential (Bogumil et al., 2012). This can be overcome through additional coordination, such as the joint

Table 2. Use of transition policies in the German hard coal phase-out according to typology by Green and Gambhir (2019) and Spencer et al. (2018).

	No support	Compensation or grandfathering (backward looking)	Structural adjustment assistance (forward-looking, narrow)	Holistic adaptive support (broad)
Workers 	At the beginning of the crisis (late 1950s), lower wages without compensation	Since early 1960s: early retirement, redundancy payments Shift of employees to the steel industry Strong social security system, unemployment payments	Retraining for workers & Financial support for entering new employment since 1954	–
Regions/ Communities 	No substantial support until mid-1960s	–	Since late 1960s: Subsidies for transport infrastructure, economic reorientation and diversification, training, education and research facilities, recultivation and refurbishment of industrial sites, creation of clusters to strengthen local industries Regional Differences: Saarland more successful in settling new companies, esp. due to 'ground lock' by coal and steel companies in Ruhr area	Since the late 1980s: Integrated transition policies covering cultural and recreational and environmental aspects to improve region's attractiveness (soft-location factors) Regional Differences: Saarland's regional identity less imprinted by coal 2010s: Ruhr area more diversified; Saarland dependent on automotive industry
Coal mining companies 	–	Since mid-1960s: compensation for price difference between domestic and imported coal Tax cuts, fiscal aid for financial stabilization (e.g. debt repayment, interest subsidies) State guarantee to cover 'eternity costs' if necessary	Modernization and restructuring payments: - for merging of mines and reductions in employment (1969–1987) - for mine closures (1963–1999)	–

Source: Own illustration based on (Bundesregierung, 1983, 1997, 2007; ECSC and EC, 1994; Frigelj, 2009; Meyer et al., 2010; Storchmann, 2005).

initiative 'MedEcon Ruhr' (Büter, 2012): this health sector initiative, involving cooperation and coordination between cities in the Ruhr area, employs more than 300,000 people and creates more than €5 billion in yearly revenues (Büter, 2012).

Table 2 provides an overview of transition policies between 1950 and 2018 based on the typology of Spencer et al. (2018) and Green and Gambhir (2019). The social policies, as well as the laws and contracts for the reduction of coal production with the coal corporations, were implemented at the national level and, hence, were the same for the Ruhr area and the Saarland. Additionally, the economic and structural policy programs implemented by the federal state governments in the two regions were very similar. The outcome of these policies for workers and corporations was mostly identical in both regions (apart from the point in time of mine closures/job losses). Some differences, however, prevail between the outcome for the regions, mainly influenced by the regions' specific situations (especially the total number of employees and economic dependence; compare Table 1). For example, although the Saarland was more successful at attracting new companies, it developed a new dependency on the automotive industry. In contrast, while the Ruhr area transformed more slowly, it managed to establish a more diversified industry structure, thus providing greater resilience to changes in a single sector.

3. Enabling a 'just and in-time transition' for coal regions

While important lessons can be identified through the two transition pathways, there is room for improvement and neither region has yet completed a *just and in-time transition*, especially as the shift to imported hard coal neglects various elements of climate and intergenerational justice concepts. Nevertheless, the historic German experience shows that, regardless of the transition specifics, certain common dimensions must be addressed to enable a just and in-time transition within regions. Important aspects can be divided into those that are relevant mainly for the mining regions and others that must be dealt with on national or international levels. In the following, important transferable experiences with structural policies, focusing on the 'just transition' elements as well as the effects on workers and the regions, are highlighted.

3.1. Reorientation by dissolving the coal and steel dominated local structures

A crucial step to enable a transition in the first place, is the urban and transportation transformation of the region to improve its connectedness with other (metropolitan) areas. The case of the Ruhr area, in particular, showed that existing urban structures were mostly concentrated around mining activities, leaving insufficient transport infrastructure for commuting to surrounding areas. The strengthening of the transport infrastructure in the Ruhr area also profited from its central European location, further encouraging the development of a strong logistics sector in the 1990s (Destatis, 2019). Adequate infrastructure is also important for regions with lower population density, helping to stop out-migration. Earlier infrastructure projects predominantly focused on constructing highways and other roads for individualized traffic; due to climate change and related air pollution targets, this is shifting toward less carbon-intensive modes of transport, such as public transport, cycle paths and railway connections (Agora Verkehrswende, 2017).

In addition to those factors visible in spatial and transportation planning that prevent a reorientation, regions are held back by other so-called 'lock-in' mechanisms: i) The resistance and lock-in of the incumbent regime, consisting of the coal and steel companies, partly joined together with politicians and trade unions; ii) problems for domestic industries caused by increasing competition due to globalization; and iii) the misjudgment of the true nature of the coal and steel crises, which prevented action implementing deeper and earlier restructuring measures (Dörrenbächer et al., 1988; Hospers, 2004). The close political links within the incumbent regime, in particular, resulted in subsidies and concessions that ensured continuity despite economic inefficiency, as seen in both case studies. Support schemes and subsidies should be directed toward new, more sustainable, industries (see section 3.2) and toward strengthening soft location factors (see section 3.3).

3.2. Attracting (new) industries and labor policies

Both mining areas had similar structural problems following the coal crisis, both looking for alternative industries. However, the close ties between established companies and politicians prevented the creation of a whole network of up – and down-stream companies in most cases. Neither the mining companies nor the state government offered their land to new companies and prevented the establishment of the Ford Motor Company in Herten and Hamm (Ruhr area) in the 1960s for example. Opel, another car company, was only able to settle in Bochum (Ruhr area) because of additional support of the municipality (Nonn, 2001). The Saarland, on the other hand, succeeded in attracting the Ford Motor Company in the 1960s through subsidies, premiums and tax concessions. This shows that the settlement of a new industry depends on the location, the timing, as well as the availability of trained workers and available space. The unsuccessful example of Nokia in the Ruhr area, however, also shows the problems of increasing competition in a globalized world. The formation of a network (of suppliers) within the area proved to be an important factor for the survival of the Saarland automotive industry through subsequent crises (Georgi & Giersch, 1977). Enlarging such networks with universities and research centers to spark innovation resulted in the formation of clusters that strengthen local industries (Heinze, 2006; Rehfeld & Nordhause-Janz, 2017).

Besides replacing mining jobs with new jobs in other industries, active and passive labor market and social policies play a major role in a just and in-time transition. Anticipative elements, like retraining and the early

communication of phase-out plans, can ease the disruption of upcoming changes, helping coal miners to stay in the labor market and encourage new generations to choose education and employment tracks with better future perspectives (Healy & Barry, 2017; Mayer, 2018; Newell & Mulvaney, 2013). In the German case, early retirement was a frequently used measure for easing labor market tensions and to help miners above a certain age (Frigelj, 2009). According to the hard coal financing law from 2007, every worker older than 42 was protected against unemployment. After the end of their employment in coal mines in 2018, workers would work three years in decommissioning and then receive payments for another five years to bridge the time until they entered the regular pension fund at age 62 in 2027 (Frigelj, 2009).

Renewable energy is a promising new employment sector for future transitions away from fossil fuel industries, with the sector already employing around 350,000 people in Germany (Egerer et al., 2018) and around 11 million globally (IRENA, 2019). Regions with coal power plants are potentially well suited as they have a high competence in energy industries, a positive connotation and historic identification with energy installations, as well as much of the needed infrastructure requirements, e.g. high-voltage electricity access or industrial complexes. It is important to ensure that lost jobs are replaced with new comparable jobs, not only in quantity but also quality (Lerch & Simon, 2011).

3.3. Including soft location factors and regional identities

Besides infrastructure, the absence of a university within a region of at least five million people highlights the former strong focus on coal and steel production within the Ruhr area. An expansion of the educational system in the mining regions is, on the one hand, important for giving the population the opportunity to adapt to the new labor market conditions. On the other hand, it helps to mitigate the threat of out-migration due to a lack of educational opportunities in the region, while also encouraging immigration from other regions. Education and research institutions can play an important role in enabling a shift from mining toward a more knowledge-based society (Kriegesmann, Böttcher, & Lippmann, 2016). Supporting higher education boosts high-value adding sectors, increasing demand for highly skilled workers and research-based innovation. In 2014, the Ruhr profited from 22 universities with more than 250,000 students (Kriegesmann, Böttcher, & Lippmann, 2015). The opening of these universities enhanced the attractiveness of the region for companies and for citizens, constituting an important location factor. Integrating universities and research facilities with networks of companies and other institutions creates competitive and resilient structures that keep companies in the region and attract new ones (Stognief et al., 2019).

Soft location factors, like cultural and leisure time possibilities, as well as environmental issues (e.g. air pollution levels and clean rivers), play an important role in the public perception of a region. They increase the quality of life in the region and can convince people not just to stay, but also to move there. In the Ruhr, the total net migration from 1977 until 1986 increased to $-158,000$.⁷ Thus, the structural policy programs 'Action Program Ruhr' (1980) and the 'IBA Emscher Park' (1989), put a specific emphasis on improving soft location factors. In the following years, former industrial sites were transformed into landmarks and cultural sites not just to celebrate the region's identity, but also to enable a shift toward a new, more future oriented, perception of the region (Goch, 2009). Subsequently, the total net migration turned positive with a population increase of $+247,000$ people between 1987 and 1995.⁸ Incorporating soft location factors into cohesion policies through the participation of local stakeholders from the start can help change perceptions and increase acceptance of upcoming transitions.

3.4. Managing the transition

A challenge for the development of structural policy was to identify the right system of governance to guide the transition, especially within Germany's federal context. The first large projects initiated at a national level were ineffective, facing both regional and local resistance. Thereafter, decision making and planning shifted to a more regional level, taking account of endogenous local potentials and enhancing public support for the transition by increasing bottom-up participation of local stakeholders (Goch, 2009). This enabled each region to benefit from its individual strengths and, simultaneously, in comparison to top-down decision making, reduced local

resistance against the transition. Additional coordination of these various polycentric measures is needed to enable an efficient and sufficiently fast transition process. The establishment of one institution with sufficient capacities representing the entire Ruhr area helped to coordinate national funding. Nevertheless, it is not always possible to create a coherent strategy for all cities within a region (Bogumil et al., 2012; Metropole Ruhr, 2018). The multicentricity of the Ruhr area means that redundant developments of cities within close proximity slowed down the transition; a more coordinated strategy would tap its full endogenous potential. Future phase-outs in regions similar to that of the Ruhr should create organizational units that are able to develop and implement such strategies in a coordinated way, thus facilitating a more efficient and rapid transition.

For the German hard coal mining phase-out, the majority of costs were linked to structural and social policies designed to slow down the economically driven phase-out, as depicted in Figure 3. A just and in-time transition requires financial resources and a fair distribution of the responsibilities for the costs. In the German case, most of the subsidies for the Ruhr and Saarland were financed through the national budget. As future coal phase-outs are expected to mostly involve political decisions motivated by global climate change concerns, costs should not only be borne by the regions but rather by the whole country, if not internationally. Furthermore, it is necessary to implement measures that secure enough financial resources from coal companies to cover the costs caused by their operations (e.g. recultivation costs and compensation of relocated settlements). For an overview of potential measures, see Oei et al. (2017).

4. Conclusion

The Ruhr and Saarland experienced a 50-year-long, predominantly economically driven decline of their coal industries. Since 1960, many different structural and societal policy measures at the national and state levels were sought to regulate – typically to slow down – the rate of necessary structural changes. The decision that most prolonged German hard coal production was to support the mining companies with public subsidies. It also meant that none of the former workers were left behind, thus securing a claim for a just and in-time transition. On the other hand, insufficient measures were taken for the creation of new potential for upcoming generations and more sustainable industries. Further, the shift to imported hard coal for power plants ignored the global climate, social, and environmental effects of burning coal. In this respect, the hard coal mining phase-out in both regions failed to achieve a just and in-time transition. Nevertheless, this analysis provides some transferable lessons on how regional resistance and structural change can be addressed in the future.

The main lessons of the two case studies with resulting recommendations are:

Refrain from subsidizing the coal industry: Instead, the formal and informal political influence of the coal companies must be weakened in order to overcome the lock-ins, thus enabling economic reorientation. Currently, G20 states are still spending around US\$39 billion on coal production each year (Climate Transparency, 2019); in line with the PPCA commitments, these should be abolished.

Take into account long-term effects and impacts beyond the local communities in decision making: The aim of leaving no one behind was not fully met, as future generations within the region as well as international actors (to account for climate and environmental justice effects along the entire value chain) were not included in the transition's decision making processes.

Listen to external independent advice in addition to the incumbent coal regime: An earlier phase-out, as recommended by academics, would have been less expensive, caused less environmental devastation, and most likely resulted in a faster recovery of the regions.

Diversification can minimize the risk as no 'silver bullet' exists: It is difficult to attract and predict the success of new industries. The Saarland was more successful earlier on; however, its new dependence on the automotive industry creates the next threat. In contrast, the Ruhr economy transformed slower but is now more diversified.

Participation enables locally adapted solutions and higher acceptance: The involvement of local stakeholders is important for identifying strengths and weaknesses of the regions in terms of adjusting, developing, and implementing local strategies.

Encourage cooperation through crossing borders: Appropriate structures must be created to enable a joint post-carbon strategy for entire mining regions, independent from administrative federal or national borders. Political institutions focused on social, labor, spatial, and energy planning must combine efforts, facilitating the establishment of an integrated, coherent policy mix.

The two cases examined involve relatively wealthy, old, industrial regions in a central European location, with relatively high population densities and proximity to supra-regional conurbations. This is a major advantage for the promotion of projects and the establishment of companies, which does not apply to all mining regions. The transition of both regions is not solely attributable to declining coal production; the diminishing importance of the steel industry also played a role. In addition, political and administrative structures are integral in the allocation of funding: Germany's federal structure enabled mining regions to acquire significantly more funds than comparable regions in other countries, thus the costs of transformation were easily externalized to the national level (Feld, Schnellenbach, & Baskaran, 2012).

The findings from this study could be used to examine differences between comparable past coal mining phase-outs, especially within Europe, e.g. the UK or Spain. Furthermore, the findings are of great importance for the ongoing German discourse on the phase-out of its remaining coal assets. In most regions, coal transitions will include a phase-out of mining and power plants, resulting in the challenges of providing new employment possibilities as well as replacing coal power plants with renewable energy sources. A comparison is also possible with coal exporting countries like Colombia and South Africa, where the focus will lie on the effect of mine closures in affected regions. Combining climate, energy, social, and structural policies, whilst recognizing both local specifics and global connections, can help guide a just and in-time transition away from fossil fuels.

Notes

1. In the following, the term transition refers to this understanding of switching from a fossil fuel-based energy system to a renewable one, with related changes on the technical, governance and social levels (Child & Breyer, 2017).
2. We conducted a search in several databases (e.g.: Elsevier, Springer Link, Google scholar and books, JStor, De Gruyter, Oxford Journals, EconBiz) looking for key word combinations both in English and German (e.g: policy, Germany, Ruhr area, Saarland, North Rhine-Westphalia, structural, innovation, transformation, labor, hard coal, economy, historical, regional, social, energy, mining). Our search resulted in a collection of around 500 related documents, of which around 100 were more closely investigated.
3. Namely: 1) "Coal Transitions": gathering lessons learned from historic coal phase-outs and future coal phase-out strategies from six major coal-using countries. 2) "Structural Change in Coal-mining Regions as a Process of an Economic and Socio-Ecological Transformation": assessment of phase-out of coal production in the Ruhr area (Germany) and the reduction of lignite in consumption in Lusatia (Germany). 3) "Coal Exit": design a socially acceptable framework for an upcoming coal phase-out in Germany, as a basis for future regional transition frameworks by, among other things, analyzing past transitions and continuous stakeholder feedback.
4. The co-determination law from 1951 gave both employers and employees equal votes on company boards in the coal and steel sector, if the total number of employees exceeded 1,000. Both sides agreed on a neutral person to avoid stalemate by votes.
5. Own calculations based on: Regionalverband Ruhr, 2017b.
6. In real terms in 2008 €. Upper value includes financial support (direct and tax breaks), benefits in the emissions trade system and the costs of higher electricity prices through incomplete competition in the electricity sector.
7. Regionalverband Ruhr, 2017a.
8. Ibid.
9. Due to lack of data, the presented data for the Ruhr area is for North-Rhine Westphalia.

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