Price and Employment Effects triggered by a German Coal Phase-Out – A Discourse Analysis

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***Abstract*—Despite significant increases in low CO_2-emission electricity generation from renewable energy sources, Germany seems off-track for reaching national climate targets for 2020. Therefore, in addition to a debate on price-based instruments to reduce emissions, a more interventionist, mandatory phase-out of coal-based power plants is discussed in Germany. For this paper, we analysed more than 30 studies on phase-out pathways, dates and other aspects of a coal-phase-out in Germany. We focus our analysis on wholesale electricity prices and employment effects. We show differences in the literature regarding both aspects and explain the causes of these differences. Our analysis reveals that the choice of a reference case, e. g. whether a retrofit option for coal power plants is practicable, and methodological differences in the form of additional constraints, e. g. the enforcement of a national secured capacity, have a crucial influence on the resulting effects from a coal phase-out.**

***Index Terms*—Coal phase-out, direct employment effects, discourse analysis, electricity price effects.**

I. Introduction

At the 2015 United Nations Climate Change Conference in Paris, 196 governments agreed to limit the increase in the global average temperature “to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels” [1]. The main source for anthropogenic climate change is the combustion of fossil fuels like coal, crude oil and natural gas [2]. Due to its significant share of global greenhouse gas (GHG) emissions and the decreasing costs of renewable energy sources for electricity generation, the decarbonization of the power sector is a key component of cost-effective mitigation strategies in achieving low-stabilization levels in the concentration of GHGs [3].

In its Energy Concept of 2010 the German government sets national climate protection targets. GHG emissions are to be cut by 40 % by 2020, and 80-95 % by 2050 as compared to 1990 levels [4]. These targets are confirmed and further specified by the Climate Action Plan 2050 which defines sector-specific GHG reduction targets for the year 2030. The power sector, as an example, must cut GHG emissions by 61-62 % by 2030 as compared to 1990 [5]. The importance of the electricity sector for decarbonization is highlighted by several studies, e. g. [6]-[8], which analyze cost-effective decarbonization pathways across all sectors. According to these sources, the electricity sector plays an important role in decarbonizing the heat and transport sectors.

As of today, despite its significant (and expensive) expansion of electricity generation from renewable energy sources (RES) (see [9] and [10]), Germany seems to be off-track for reaching national climate targets for 2020. Until now, this expansion of low CO_2-emission electricity generation mostly replaced low CO_2-emission electricity generation from nuclear power stations.[1]

In addition to a debate on price-based instruments, e. g. a minimum CO_2-emission price [12]-[14] or cost-efficient instruments within the electricity sector [15], a more interventionist, mandatory phase-out of coal-based power plants is widely discussed in Germany.

We considered more than thirty studies and scientific papers regarding this topic. Several studies propose phase-out pathways and dates, based on German climate protection targets ([16]-[20]) or remaining CO_2 budget ([21] and [22]). The proposed phase-out year varies within the range of 2025 and 2050. Other papers discuss the effects of a mandatory coal phase-out on CO_2 emission reduction ([14], [16], [18]-[20], [23] and [24]), focus on security of supply ([16]-[18], [20], [21], [23], [24], [25]), or give a legal evaluation of a mandatory phase-out of coal-based power plants ([26] and [27]).

[1] Germany decided to phase-out nuclear after the Fukushima accident in Japan in 2011. Electricity generation from nuclear decreased from 140.6 TWh in 2010 (23 % of German electricity consumption) to 76.3 TWh in 2017 (13 %). In the same period, electricity production from coal decreased from 262.9 TWh (43 % of German electricity consumption) in 2010 to 241.9 TWh in 2017 (40 %), whereby electricity production from lignite slightly increased by 2.5 TWh. [11]

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In this paper we focus on economic effects, in particular wholesale electricity prices, and employment effects in the coal industry, triggered by a phase-out of coal-based electricity production in Germany. Table I shows the eight (out of the thirty) papers which contain quantitative estimates of either electricity prices or employment effects.

TABLE I: ISSUES CONSIDERED IN THE SELECTED PAPERS

Paper	**Issues**			
	Electricity prices	***Employment***	***CO_2 emission reduction***	***Security of supply***
[14]	X		X	
[16]	X		X	X
[19]	X		X	
[20]	X	X	X	X
[23]	X		X	X
[24]	X		X	X
[28]	X	X		
[29]		X		

In all eight papers, the determination of these effects is done in two steps. In the first step, based on the modeling of the electricity market, a reference scenario is simulated. A reference scenario (also referred to as “business-as-usual” or “current policy” scenario) models development on the electricity market, e. g. the development of CO_2 emissions and capacity expansions, based on current instruments. Therefore CO_2 emission reductions are only based on the European Union Emissions Trading System (EU ETS) and other adopted measures, e. g. transferring lignite power stations units in Germany to the emergency pool of reserve power. Furthermore, power plants are decommissioned at the end of their life-time or because of missing economic viability. Investments in new power plants are decided endogenously. In the second step, a reduction or even a complete phase-out of coal power plants in Germany is simulated. The coal phase-out scenarios are oriented to German climate protection targets – either on the Energy Concept 2010 ([16], [19], [24], [28]) or the Climate Action Plan 2050 ([14], [20], [23], [29]). Apart from [20], the coal phase-out is modeled by the exogenously determined decommission of coal power plants. Reference [16] analyzes different phase-out pathways, which differ in the speeds with which coal power plant capacity is reduced. Thereby, the influence of phase-out speed on national CO_2 reduction and electricity prices is investigated. Out of these phase-out scenarios, [24] and [28] choose the one with the average phase-out speed, which results in a coal exit in the year 2040. In [14] the reduction of lignite capacity is compared with a reduction of both lignite and hard coal capacity. References [19] and [23] exogenously reduce installed coal capacity until a predetermined CO_2 target is achieved. The order in which coal plants are decommissioned is based on their CO_2 abatement costs or their year of commissioning. In [20] the coal phase-out scenario is modeled endogenously by yearly CO_2 emission limits for the total electricity production in Germany.

Both scenarios provide electricity generation, CO_2 emission, installed capacity and electricity prices as output. The number of employees in the coal industry is derived from the development of installed capacity and electricity production or fuel demand of coal power plants. Finally, the effects on CO_2 emissions, electricity price and employment are determined by comparing the results of step 2 (coal phase-out scenario) with the results of step 1 (reference scenario).

The main contribution of our paper is a presentation of the wide range of results regarding economic and employment effects and an explanation of why they occur. For this purpose, we analyze the above mentioned literature regarding assumptions, methods and results.

The paper is structured as follows: Section II presents the wide range of results regarding effects on electricity prices and analyzes the reasons for the differences. The employment effects are presented and analyzed in section III. Finally, section IV summarizes our main findings.

II. EFFECT ON ELECTRICITY WHOLESALE PRICES

We define the price effect resulting from a coal phase-out as the price difference between a study’s reference scenario and the same study’s coal phase-out scenario. As Figure 1 shows, the projected price effects range from 0.8 to 14 €/MWh with an average of 3.9 €/MWh.

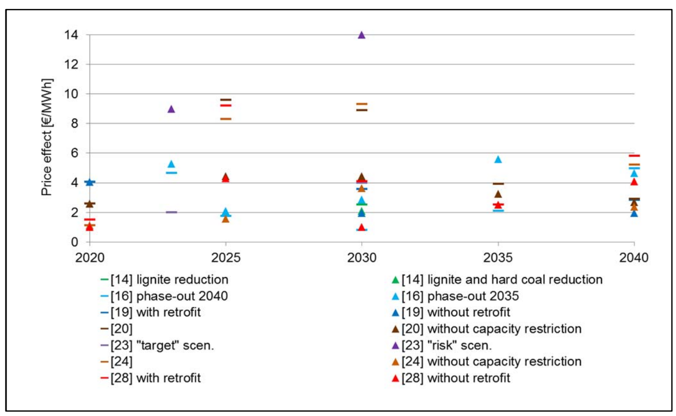

Figure 1. Price effect over time

These different price effects result from three main differences between the papers:

1. Level of coal capacity reduction
2. Fuel and CO_2 price assumptions
3. Methodological differences

Level of capacity reduction

Figure 2 shows the price effects against the coal capacity reductions (always compared to the same study's reference scenario). With the exception of [20], we can observe that a higher reduction of coal capacity leads to a greater effect on electricity prices.

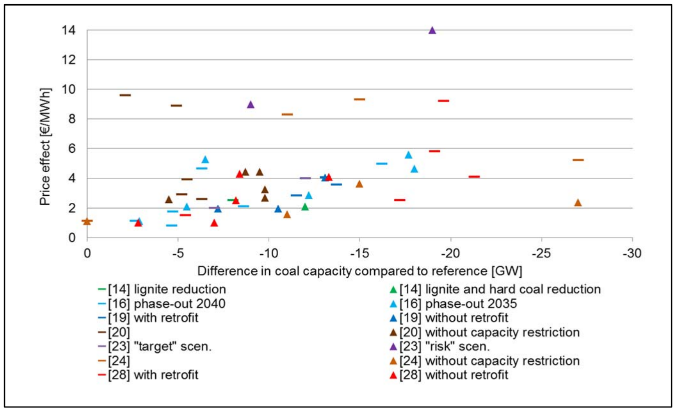

Figure 2. Price effect due to coal capacity reduction

The reason for this is that the generation by technologies with comparatively low (lignite) and medium (hard coal) generation cost are replaced by high cost technologies (gas) and imports from neighboring countries. As low cost technologies in neighboring countries are almost fully utilized, additional electricity exports to Germany are achieved mainly by high cost technologies (gas).

What are the reasons for different assumptions on reduction of coal capacity? One reason could be a different phase-out speed. Reference [16], as an example, compares a coal phase-out by 2035 with one by 2040. For the year 2030, the earlier phase-out results in 7.5 GW less coal capacity and a 2.1 €/MWh greater price effect.

Another reason for different assumptions on reduction of coal capacity is the assumed development of coal capacity in the reference scenario. As the coal phase-out scenarios are oriented on similar targets for CO_2 reduction, the need for coal capacity reduction to achieve these targets is mainly determined by the development in the reference scenario. The development of coal capacity is determined by the assumptions about their technical life-time. In this regard, the analyzed studies differ in whether an investment in the extension of the life-time, so-called retrofit, is possible or not. References [20] and [24] consider a retrofit option for coal plants, which extend their life-time by about fifteen years. An exclusion of retrofit for coal power plants, at least in Germany, is assumed by [16]. In order to determine the effects of retrofit, [19] and [28] analyses two reference scenarios – one with and one without a retrofit option for coal power plants. As presented in Figure 3, it results in different declines in the net installed coal capacity in the reference scenarios. Reference scenarios, which consider retrofit for coal power plants, lead to significantly stronger price effects. References [19] and [28] calculate that the additional price effect by consideration of retrofit accounts for 1.6 and 3.1 €/MWh in 2030, i.e. for 45 % and 76 % of the total price effect.

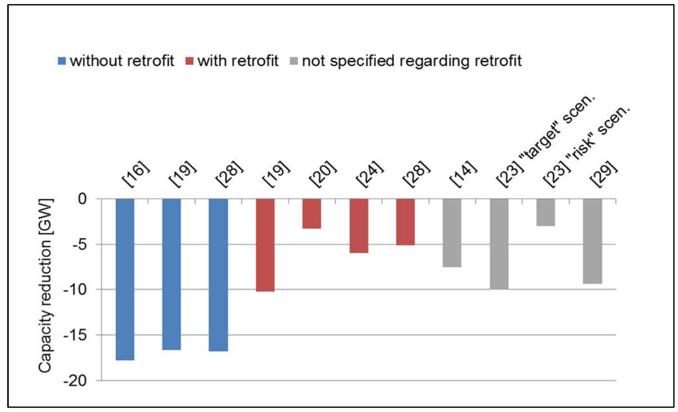

Figure 3. Coal capacity reduction between 2020 and 2030 in reference scenarios

Fuel and CO2 price assumptions

The relative marginal cost differences between generation technologies are more relevant for the dispatch order (and thereby their profitability) than their absolute level. Therefore, the competition between electricity generation by hard coal and electricity generation by gas is driven by fuel price differences and CO_2 price assumptions.

As shown in Figure 4, import prices for natural gas exceeded import prices for coal by a factor of 1.5 to 2.8 in the past eight years. Interestingly, most studies on a coal phase-out are close to the upper limit of that range (on average, the studies assume a factor of three for the year 2030).

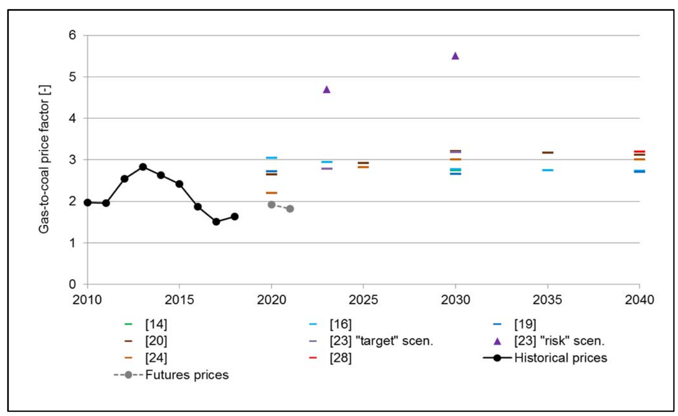

Figure 4. Gas-to-coal price factor (in 2017 prices)

The "target" scenario of [23] assumes a factor of 3.3. In contrast, their "risk" scenario assumes, with a factor 5.5, an opposite price trend between natural gas and hard coal. A higher gas-to-coal price factor leads to an increasing cost advantage of electricity production by coal over electricity production by gas. It results in two effects. Firstly, it leads to higher coal capacity in the reference case (see Figure 3) and, thereby, greater reduction of coal capacity to fulfill national emission targets. Secondly, the increased electricity production by gas caused by the reduction of coal capacity is comparably expensive. Both effects account for an additional price effect of 10 €/MWh in 2030, i.e. 71 % of the total price effect.

With regard to CO_2 prices, all analyzed studies assume increasing CO_2 prices over time. Nonetheless, the projection range is wide (see Figure 5). At least in part, this simply reflects high uncertainty regarding that parameter: the historical development of CO_2 prices is characterized by high volatility. Furthermore, newer studies tend to assume higher CO_2 prices, reflecting the recent increase in prices observed from 2018. Nevertheless, in the medium-term, all studies underestimated the current CO_2 futures prices. Hence, the profitability of carbon-intensive electricity production (lignite and hard coal) is overestimated. This results in an overestimation of remaining coal capacity in the reference scenarios and increases the needed capacity reductions in the coal phase-out scenarios. In summary, an underestimation of CO_2 price leads to an overestimation of the price effect triggered by a phase-out of coal based electricity production in Germany.

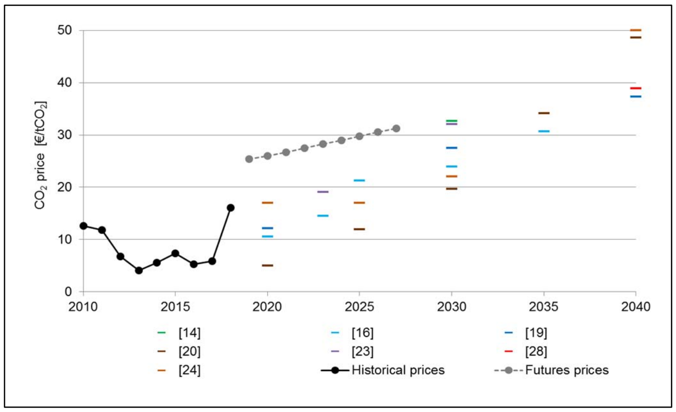

Figure 5. CO_2 price assumptions (in 2017 prices)

Methodological differences

In electricity market models, the electricity price in a specific hour and in a specific market area are determined by the derivation of the corresponding electricity balance (sum of generation is equal to the demand) with respect to electricity demand. Therefore methodological differences in the form of additional constraints - as long as they are binding - increase the electricity prices.

One of these additional constraints, used in [20] and [24], enforces that 90 % of yearly peak demand is covered by national secured capacity. This constraint has a minor effect on the reference, but a significant effect on the coal phase-out scenario. Due to the enforcement of a national secured capacity, the coal and gas capacity in the reference scenario of [20] are increased by 2.8 and 0.8 GW in 2030 respectively. In the corresponding coal phase-out scenario, the coal and gas capacity are increased by 8.4 and 2.8 GW in 2030 respectively. Therefore this constraint results in higher back-up capacities in the coal phase-out scenario and, ultimately, in price effects between 8.9 and 9.3 €/MWh in 2030. The cost for national secured capacity accounts for 50 % and 61 % of the price effects. In [18] it is argued that a national approach for secured capacity is no longer appropriate and too simple as it does not consider the balancing effects between connected electricity markets.[2]

In contrast to the other seven studies, [20] models the coal phase-out endogenously. The coal phase-out is ensured by constraints which limit the yearly CO_2 emissions caused by the total German electricity production. If these constraints are binding, then they have the same effect as a national minimum price on CO_2 emissions.[3] It increases the marginal cost of coal as well as gas power plants in Germany – in absolute terms, but also relative to neighboring countries. The differences between a mandatory coal phase-out and a national CO_2 emission limit can be shown by comparing [14] and [20], as both assume the same CO_2 reduction target for 2030. Although the coal capacity is reduced to a smaller extent, a national limit for CO_2 emissions reduces electricity production from coal and gas in Germany. The reduction of electricity production in Germany is offset by an increase in electricity imports. This explains, at least to some extent, why the resulting price effect in [20] exceeds more than twice the price effect in [14], even without an enforcement of national secured capacity.

With respect to results without retrofit, national secured capacity and other previously discussed price drivers, the average price effect is 2.1 €/MWh in 2030, with a range between 0.8 and 3.6 €/MWh. With regard to the level of coal capacity reduction, it results in an average price effect of 0.21 €/MWh per GW, with a range between 0.14 and 0.27 €/MWh per GW. In contrast, the results with retrofit, national secured capacity and other previously discussed price drivers, yield, on average, a three-fold increase in the price effect.

III. Effects on Employment

The literature on German coal phase-out distinguishes three kinds of employment effects: direct effects, indirect effects and induced effects.

1. Direct effects arise directly within the coal industry, i.e. in lignite mines and in lignite and hard coal power plants.
2. Indirect effects arise within the immediate upstream industries, i.e. component suppliers and service providers of the coal industry.
3. Induced effects arise from consumer demand triggered by direct and indirect employment. The consumer demand, in turn, triggers production in other economic sectors and thereby employment.

[2] The peak demands of different European countries occur at different points in time. Furthermore, there are spatial balancing effects regarding RES production.

[3] The CO_2 emission price reflects the shadow price of the limitation of CO_2 emission allowances within the ETS. Analogously, a national CO_2 emission limit provides a national price for CO_2 emissions, which reflects the shadow price of that limitation.

At the end of 2018 about twenty thousand people were directly employed in the German lignite industry. For Germany as a whole, studies estimate that each employee in the lignite industry creates 1.8 further jobs due to indirect and induced effects.[4] Reference [33] estimates that between four and eight thousand people are directly employed in hard coal power plants and that each of them creates 1.2 further jobs due to indirect and induced effects.

In the literature on German coal phase-out, two metrics are used to quantify direct employment effects in the coal industry:

1. Lost employment potential: Employment needs in a reference scenario are compared with employment needs in a scenario with a mandatory phase-out of coal power plants.
2. Affected workforce: Current employment less projected retirement entries are compared with employment needs in a scenario with a mandatory phase-out of coal power plants.

The first metric determines the reduction in future employments needs, due to the reduction of coal capacity triggered by a mandatory phase-out of coal power plants. The second metric addresses rather the question how many employees will have to retrain. While young employees join other companies, retired employees leave the workforce. In this paper we focus on the first metric – the lost employment potential.

A separate estimation for the lignite mining and the lignite power sector is done by [29]. Reference [20] determines employment effects for the lignite industry as a whole. Employment effects in coal power plants are analyzed by [28], treating lignite and hard coal power plants separately.

Figure 6 presents the results with regard to lost employment effects in the lignite industry and lignite power plants.

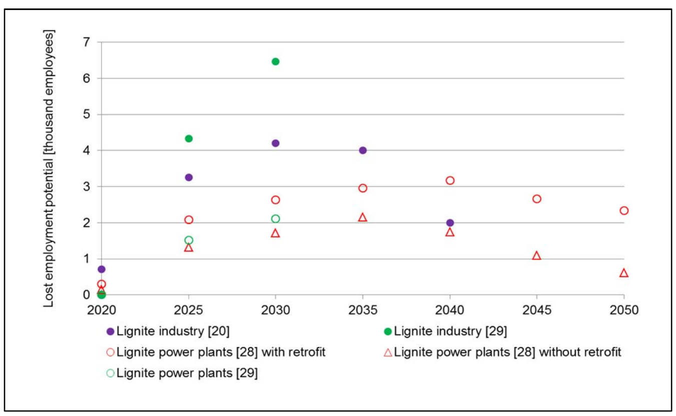

Figure 6. Lost employment lignite industry and lignite power plants

[4] The number of employees in lignite industry without employees for recultivation of lignite mines is based on [30] and [31]. Indirect and induced effects for the lignite industry derived from regional factors are based on [32].

All projections find an increase in the lost employment effect in the period between 2020 and 2030. After reaching its maximum between 2030 and 2040, the lost employment effect decreases. This trend is based on the difference between the coal capacity levels in the reference and coal phase-out scenarios. By achieving the end of their technical life-time or due to missing economic viability, coal power plants are also decommissioned in the reference scenario. As a consequence, in the long-term, the employment needs also decrease without a mandatory coal phase-out.

Although [20] assumes the same emission reduction in the electricity sector until 2030 as [29], they reach a different result regarding lost employment potential for the lignite industry as whole. Reference [20] determines that the consideration of national emission goals in the electricity sector in Germany reduces the employment need by about 2,800 employees per year on average between 2020 and 2040. At its peak in 2030, the lost employment potential amounts to about 4,200 jobs, i.e. 2,260 less than [29]. Due to methodological differences, i.e. a national CO_2 limit and national provision of secured capacity, the reduction of lignite capacity in [20] occurs more slowly than in [29]. Therefore employment effects occurring in lignite power plants are reduced in [20].

For the lignite power plants alone, [28] projects a lost employment effect of between 1,700 (without retrofit) and 2,600 (with retrofit) employees in 2030, i.e. that the exclusion of retrofits causes about 35 % of the employment effect. In later years, the difference between the employment effects with and without retrofit increase, so that 73 % of the employment effect in 2050 is caused by the exclusion of retrofits.

The remaining difference between the employment effects of [29] and [28] (without retrofit) can be explained by the different speed in reducing lignite capacity caused by different emission targets for 2030 (-62 % in [29] against -57 % in [28]).

IV. Conclusion

This paper provides an analysis of the literature on German coal phase-out with a focus on economic effects, in particular wholesale electricity prices, and employment effects in the coal industry. Our analysis shows that differences with regard to methodology as well as assumptions have a crucial influence on the resulting effects of a coal phase-out. In particular, the consideration of a retrofit option for coal power plants in the reference scenario, increase the level of capacity reduction in the coal phase-out scenario and, thereby, it has an increasing effect on the yearly average electricity price and on employment. The same holds true for an increasing fuel price difference between natural gas and hard coal. The modeling of a national, secured capacity provision and/or national CO_2 emission limits has an increasing effect on prices, but a decreasing effect on employment. The reason for this is that, both cause additional costs (capacity cost and minimum CO_2 price), but slow down the reduction of coal capacity.

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