Published in final edited form as:
Nat Energy. 2019 August 06; 4(10): 856–863. doi:10.1038/s41560-019-0460-9.

Germany's decision to phase out coal by 2038 lags behind citizens' timing preferences

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Abstract

Coal-fired power generation is the single most important source of carbon dioxide emissions in many countries, including Germany. A government commission recently proposed to phase out coal by 2038, which implies that the country will miss its 2020 climate target. Based on a representative sample of German voters assessing 31,744 hypothetical policy scenarios in a choice experiment, we show that voters prefer an earlier phase-out by 2025. They would uphold their support for greater climate ambition up to an additional cost to society of €8.50 billion. Voters in Rhineland and Lusatia, the country's main coal regions, support an earlier phase-out, too, although to a lesser extent. By demonstrating that political decision-makers are more reluctant to overcoming energy path dependence than voters, our analysis calls for further research explaining the influence of particular stakeholders in slowing energy transitions.

80 per cent of the world's coal reserves must stay in the ground in order to reach the target of limiting global warming to well below 2 degrees Celsius compared to pre-industrial levels[1]. Already in 2008, climate scientists had called for a complete divestment from coal-fired electricity by 2030[2], a proposition reiterated by a recent "Roadmap for Rapid Decarbonization"[3]. Yet, despite the strong growth of renewable energies, coal still accounted for 28 percent of the world's primary energy supply in 2017[4]. As Pfeiffer et al.[5] point out, coal-fired power plants "will need to be underutilized, retired early, or retrofitted […] or—in short—stranded" (p. 7) if countries are serious about reaching the targets set out in Paris.

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Ethics statement. We have complied with all relevant ethical regulations and guidelines for study procedures set forth by the Ethics Committee of the University of St.Gallen. The survey for this study was fielded by Kantar/Lightspeed, and all respondents were first informed about the nature of the study before being asked to consent.

Data availability statement. Replication data for the study are available in the Harvard Dataverse with the identifier https://doi.org/10.7910/DVN/TEFCBL (ref. [63]).

Code availability statement. Replication code for the study is available in the Harvard Dataverse with the identifier https://doi.org/10.7910/DVN/TEFCBL (ref. [63]).

Author contributions
A.R. designed the study and analyzed the data. A.R. and R.W. wrote the paper.

Competing interests
The authors declare no financial and non-financial competing interests.

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As private markets will not spur such necessary developments on their own, government policies play an important role in phasing out coal[6,7]. However, in democratic countries, such policies may face public opposition. While several studies suggest that the global energy transition (i.e., shifting from non-renewable to renewable energies) is likely to lead to net job creation in most economies[8], the closure of coal mines and coal-fired power plants may lead to temporary and regionally concentrated job losses. Anticipating negative employment effects could lead to opposition by those working in the sector[9]. Moreover, the coal industry has become an identity-shaping symbol deeply engrained in the culture of some communities and countries, such as in the German region of Lusatia[10], Silesia in Poland[11], or Appalachia in the United States[12]. Opposition to a phase-out of coal is also likely to be fueled by the economic actors that have to bear parts of the costs, such as utilities whose business models depend on coal, and labor unions representing coal workers. Given their desire to be re-elected, democratic governments may be responsive to these concerns.

At the same time, recent assessments such as the IPCC's Special Report "Global Warming of 1.5°C" emphasize the urgency of ambitious action to prevent irreversible climate change[13]. While some jurisdictions have committed to phasing out coal, such as Canada and the United Kingdom who launched the Powering Past Coal Alliance in November 2017, many others are not delivering policies ambitious enough to meet the climate challenge. Germany, the largest energy consumer in the European Union, the world's largest producer of lignite and one of the top 10 coal-burning countries in the world[4], has recently started to organize its departure from coal.

Germany has heavily relied on coal for power generation for a long time. In the 1950s, more than 500,000 people were employed in the sector, contributing to the German "Wirtschaftswunder" after World War II[14]. While the oil crisis in 1973/74 gave a push to the development of nuclear power, domestic coal was seen as important to ensure energy security, and utilities were thus required to burn a quota of domestic hard coal[15]. As operating costs in the coal industry had started to outpace market revenues in the 1960s, the federal and state governments introduced subsidies for hard coal mining. These amounted to more than €320 billion until they were phased out in 2018[16].

In the 1970s, coal-fired generation started to become more controversial. The environmental movement and (later) the newly established Green Party opposed coal-fired power plants and open pit mining, but were even more concerned with nuclear power, largely avoiding simultaneous contestation on two fronts[14]. The coal industry nurtured strong ties to the country's two largest parties, Christian Democrats (CDU/CSU) and Social Democrats (SPD), with the latter in particular aiming at keeping coal mines open as long as possible[14]. In the wake of the 1986 Chernobyl nuclear accident, Germany adopted a policy framework for the promotion of renewable energies in 1990[17], which started to fundamentally change electricity markets. The share of power generated by renewables soared from 3.6 to 35.2 per cent between 1990 and 2018[18].

While Germany has been successful in transitioning from nuclear to renewable energy, 35.3 percent of electricity generation still relied on coal in 2018 (Figure 1). Adding policy

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support for renewables is an important element in decarbonizing the energy sector[19], but whether layering support schemes for sustainable technologies on top of the existing institutions[20] without addressing the legacy of fossil fuels is enough to "effectively lead energy systems out of carbon lock-in" (ref. [21], p. 1171) is an open question. Given only gently decreasing emissions (Figure 1), the question of a coal phase-out gained prominence in the aftermath of the adoption of the Paris Agreement. In November 2016, the German government adopted the "Climate Action Plan 2050", outlining measures to achieve the country's climate targets. This plan failed to develop a phase-out strategy, and in 2018 the task was delegated to the Coal Commission, an expert Commission on growth, structural change and employment consisting of a variety of stakeholders including industry associations, labor unions, state-level governments, environmental non-governmental organizations and independent scientists appointed by the federal government. In early 2019 this group recommended to phase out coal-fired power generation by 2038, proposing a broad array of measures to support the coal regions in restructuring their economies.

In light of recent concerns about populist backlash against climate policy[22,23], some observers consider the proposed timeline as a reasonable compromise between public acceptance and climate change mitigation. Although the compromise has been praised for representing a broad societal consensus, given the urgency of ambitious climate action[3,13], some members of the Coal Comission have criticized the plan as not ambitious enough (ref. [24], pp.118-119) to deliver on Germany's climate policy targets.

Given these concerns, and the view expressed in the German Climate Action Plan that public support is a central precondition for successful implementation of climate policies (ref. [25], p. 15), we investigate whether the recommendations of the Coal Comission are in line with voters' preferences, in particular regarding the temporal dimension. First, we investigate how citizens' support for a coal phase-out is affected by different timelines and other features of a phase-out, and examine the moderating influence of political orientation and climate change-related beliefs. Second, we explore the preferences of citizens living in Germany's two largest coal regions, Rhineland and Lusatia. Our analysis suggests that compared to the recommendations of the Coal Commission, a more ambitious timeline for phasing out coal would actually have been more in line with citizens' preferences.

Effects of phase-out design on public support

Based on data from a large-scale choice experiment, we examine how public preferences for a coal phase-out in Germany are affected by different proposed timelines for a phase-out, and compare citizens' preferences with the recommendations of the expert commission. We also investigate the role of other policy attributes (cost, effects on jobs, and supporting measures for the transformation of the coal regions; see Table 1 and Methods section for details). Our analysis is based on an online survey administered to a nonprobability but representative sample of 2,161 Germans who are eligible to vote (see Supplementary Table 1). The choice experiment involved a rating task whereby respondents were exposed to eight consecutive pairs of hypothetical policy scenarios to phase out coal. In the scenarios, the attribute levels of the phase-out policy were varied randomly. Participants were asked to rate these scenarios on a scale from 1 ('very poor') to 7 ('very good'). To ease interpretation of

the marginal effects shown below, the rating scale was dichotomized, using the median (which is 4) as cutoff value. The resulting dependent variable *Phase-out Support* is hence coded 0 for cases where a respondent rated a proposal as poor to neutral (1 to 4) and 1 for cases where (s)he was (rather) positive about it. The fully randomized design allows us to estimate the causal effects of multiple treatment components simultaneously using simple linear regression[26]. The subsequent analyses are based on a sample of 1,984 Germans evaluating 31,744 policy scenarios. This sample is cleaned of respondents who failed to correctly answer an attention check implemented in the choice experiment. However, all results discussed in the paper remain substantively the same when replicating the analyses including the inattentive respondents (see Supplementary Tables 2, 4, 6, 8 and 10).

Figure 2 shows the marginal effects associated with each attribute level based on regression analysis (Supplementary Table 2), using the dichotomized rating outcome as dependent variable and standard errors grouped at the level of the respondent (clustered standard errors). For the timing attribute, we take 2040 as reference category, as this level most closely matches the 2038 timeline ultimately recommended by the Coal Commission. We find that policy scenarios with 2025 as end date have a significantly higher probability of being supported than policies with later end dates. Postponing the phase-out to 2040 leads to a decrease in policy support by 10.7 percentage points, and postponing it to 2100 – as reflected in the G7's statement to phase out fossil fuels by the end of the century – leads to a further decrease in policy support by 15.3 percentage points, compared to 2040. As becomes apparent, Germans are also sensitive to the cost of a coal phase-out. Every increase in annual cost of €10 per household (or about €400 Mio. p.a. for the German economy as a whole) decreases public support by about seven percentage points. With regard to employment effects, people prefer scenarios with lower job losses over scenarios with higher job losses, but they value newly created jobs slightly higher than lost old jobs. For instance, while 20,000 lost jobs decrease phase-out support by 9.2 percentage points compared to a scenario with only 5,000 lost jobs, creating the same number of new jobs increases phase-out support by 12.2 percentage points. The type of supportive measures for the local economy is the least important of the five attributes. Among the design options offered here, the preferred attribute level is an expansion of renewable energies.

Partisan differences and gateway beliefs

As the discussions in the Coal Commission showed, the main question about phasing out coal is not if, but when the phase-out is going to happen. Hence, the following analyses focus specifically on the question of timing. While Figure 2 indicates that the timeline does indeed have a considerable effect on citizens' preferences, there may be differences between population subgroups. In particular, it has been suggested that party identification structures people's energy policy preferences[27,28]. Germany's party elites represent opposing views on the coal phase-out, ranging from the Green Party's position for an early phase-out to the conservative parties tending to defend the status quo[29]. In the context of the federal elections in 2017, the partisan divide on the topic became highly visible, and the question of timing was one of the reasons why the negotiations for a government coalition consisting of the Christian Democrats, the Liberal Democrats (FDP) and the Green Party failed in November 2017[30]. Figure 3 (a) shows that there is some variation among different partisans with regard

to the strength of their timing preferences. Unsurprisingly, Green party supporters show the strongest preference for an early phase-out in 2025. What may be more surprising is that supporters of almost all other parties prefer 2025 over 2040, too. The only exception is the relatively small subsample supporting the Bavarian arm of the Christian Democrats (CSU), where the preference for 2025 is not significant. In contrast to public statements by their party leaders, FDP and Green Party voters have fairly similar views on this issue. For all respondents, phasing out in 2100 is the least preferred timeline, although supporters of the right-wing populist party Alternative fuer Deutschland (AfD) are comparatively more positive about such a late phase-out date than supporters of all other parties. In light of other surveys investigating public attitudes on the German energy transition more broadly[31] or the coal phase-out specifically[32], the muted differences across different partisans actually reflect a recurring pattern. See Supplementary Table 3 for the supporting regression analyses.

We also expected beliefs about climate change to be relevant in conditioning the influence of phase-out timing on citizens' support. We assessed climate change-related beliefs by asking respondents to estimate the share of global climate scientists who think that the rise in the atmospherical CO_2 concentration since the mid-20th century is primarily due to human activities. Perceived scientific consensus about the anthropogenic nature of current climate change functions as a "gateway belief" that influences several other climate change and energy-related attitudes[33–36]. While quantifications show that the consensus is shared by 90 to 100 percent of publishing climate scientists[37], a recent study conducted in the US highlights that only 15 percent of Americans are aware of this high level of consensus[38]. In our German sample, the mean estimate of consensus is 66 percent (SD = 22.9), and 18.3 percent of respondents estimate the consensus to be 90 percent or higher. Figure 3 (b) shows that perceived consensus indeed strongly moderates the effect of phase-out timelines on preferences. Respondents who think the consensus is below 50 percent are indifferent to whether the proposed end date is 2025, 2030 or 2040, but their support still decreases if coal is phased out by 2100. The closer respondents' climate-related beliefs approximate the true level of scientific consensus, the more pronounced their preference for an earlier phase-out. Respondents who (accurately) estimate the consensus to be 90 percent or higher prefer a 2025 phase-out date by more than forty percentage points over a phase-out at the end of this century. See Supplementary Table 5 for the supporting regression analyses.

Ties to coal industry weaken support for early phase-out

To explore the influence of social embeddedness on preferences for a coal phase-out, we rely on two additional samples including residents of the two main coal regions, Rhineland (n = 533) and Lusatia (n = 501), who took the same survey. Within these independently collected regional samples, we further investigate whether the preferences of people having direct ties to the coal industry, for example, through acquaintances or by being employed in the sector, differ from those of other respondents in the region. The results (Figure 4, for supporting regression analyses see Supplementary Table 7 and Supplementary Table 9) suggest that people in the coal regions have less pronounced preferences for an early phase-out than respondents in the nationwide sample. However, there are some differences between the two regions. Phasing out coal until 2025 or 2030 instead of 2040 leads to significantly higher support in Rhineland, while respondents in the Eastern German region of Lusatia tend to

support a phase-out in 2030. Even here, later phase-out dates are significantly less preferred. Differentiating between respondents with strong (red symbols in Figure 4) and weak (blue symbols) social ties to the coal industry suggests that in both regions, people with strong ties are indifferent between phasing out in 2025, 2030 or 2040, as the confidence intervals around the point estimates for 2025 and 2030 include the dotted reference line.

Conclusion

Effectively and rapidly addressing climate change not only requires investing in new energy technologies, but also divesting from carbon-intensive energy infrastructures[39–43]. Our study is among the first to investigate citizens' views on the second part of this equation. Based on a large-scale survey, we assessed German voters' preferences for different design options of policies to phase out coal. We found that the average respondent consistently prefers a more ambitious timeline. All else being equal, the preference was to phase out coal by 2025, as opposed to the Coal Commission's proposal of phasing out only in 2038. A particular strength of our methodological approach is that doing choice experiments allows us to scrutinize respondents' timing preference in relation to possible trade-offs with other attributes of an accelerated phase-out, such as higher cost. By comparing preferences across attributes, we find that support for an accelerated phase-out is upheld up to an additional cost to society of €8.50 billion (see Supplementary Figure 1).

Acceptance of policy proposals is also sensitive to employment effects of the energy transition. Cost matters, and so do job losses. If delaying the phase-out from 2025 to 2030 would result in halving job losses from 20'000 to 10'000, voters would – all else being equal – accept the later phase-out. At the same time, our analysis shows that job creation matters even more than job losses. Policymakers aiming at finding support for ambitious climate policies are therefore well-advised to make credible claims about how these policies will lead to new employment opportunities in low-carbon industries.

Our results also shed light on similarities and differences between various population segments. Looking at party identification, preferences for earlier over later phase-out dates are widespread among almost the entire political spectrum. In addition, even voters in Germany's two largest coal mining regions share – to a large extent – the preference for an earlier over a later phase-out. The only notable exception are citizens with strong ties to the coal industry, who have no significant preference for a 2025 phase-out over one that happens only in 2030 or 2040. Similarly, voters in the Eastern German region of Lusatia slightly prefer 2030 over 2025 as the phase-out date. Moreover, knowledge about the scientific consensus on anthropogenic climate change is an important predictor of supporting an ambitious phase-out. Slightly less than a fifth of respondents are aware that more than 90 percent of climate scientists agree that climate change is manmade. These well-informed respondents have a stronger preference for phasing out coal in 2025 than those who (erroneously) believe that no such consensus exists.

In light of our findings, the German Coal Commission's proposal to phase out coal by 2038 does not appear to correspond well to voter preferences. This might be an indication that commission members over-estimated voters' conservatism, as political elites have been

shown to do frequently[44,45]. However, even assuming that the commission members gave constituents in coal-mining regions precedence over voters in other parts of the country would not explain why such a late date has been chosen, as even in those regions respondents preferred phase-out dates between 2025 (Western Germany) and 2030 (Eastern Germany). An alternative explanation for this mismatch is that voter preferences simply did not play a decisive role in the consultations of the commission. As Figure 5 illustrates, citizen voices (e.g., represented by non-governmental organizations) were rather under-represented among the 28 commission members. Moreover, most commission members were insulated from re-election pressures, and some might have emphasized short-term economic interests, such as the Confederation of German Employers' Associations (BGA) or the trade union representing workers in mining, chemicals, and energy (IGBCE). While a detailed analysis of the decision-making dynamics within the commission is beyond this paper's scope, the strong representation of incumbent interests within the commission highlights an important institutional barrier against overcoming energy path dependence. Further work in this area could investigate the ability of corporatist styles of decision-making in reforming today's carbon-intensive energy systems[46]. To successfully manage "the next phase of the energy transition"[47], which implies making established technologies and infrastructures redundant, we need to enhance our understanding of incumbents' survival strategies, including their corporate political activity aimed at slowing down the transition. Moreover, given the prevalence of particular stakeholders stressing job losses rather than new opportunities, the nexus between employment considerations and the political feasibility of decarbonization measures needs more scholarly attention[8,48]. Energy transition researchers and modelers would benefit from engaging with political scientists and sociologists to unveil the interests and activities of various actors shaping energy policies. Policymakers trying to successfully develop ambitious climate change mitigation policies should be encouraged to find ways of being exposed to a balanced view of the risks and opportunities of the energy transition. Our results suggest that in a democratic setting, such action could be rewarded in future elections by voters.

Methods

Choice Experiment Rationale and Design

To investigate voters' policy preferences, we conducted a choice experiment. Choice experiments were developed in marketing research to investigate the importance of different product design features in determining purchasing preferences. The idea is to put respondents in a hypothetical yet realistic choice situation in which they are confronted with bundles of relevant product attributes. By observing stated preferences with regard to the presented alternatives, it is possible to examine the relevance certain product attributes and their specific characteristics have for individual choices.

Political scientists have adopted the method to gauge citizens' preferences with regard to different policy proposals or scenarios[26,49]. Analytically, the design features of a policy are similar to product attributes, which is why the method provides a powerful approach to simultaneously estimate the individual effects of several attributes of a policy proposal on voter preferences[50]. Choice experiments require decision-makers to make trade-offs between

different policy attributes when evaluating various multidimensional alternatives. As a consequence, they can mitigate the problem of social desirability bias in public opinion research on environmental matters[26]. In our case, using choice experiments may reduce the likelihood of overestimating voters' appetite for an ambitious phase-out of coal.

At the beginning of the choice experiment, respondents were made familiar with five attributes of a potential policy to phase out coal: the timescale of the phase-out, estimated costs, effects on employment in terms of layoffs and newly created jobs, and supporting measures for the transformation of the coal regions. We selected these five attributes due to the following considerations. In 2017 the German Advisory Council on the Environment (SRU), an expert advisory panel to the federal government, recommended a staged approach in which the coal-fired power plants with highest emissions would be disconnected from the grid as early as 2020[51]. The most efficient power plants would be successively shut down in the 2030s, and the phase-out would be completed by 2040 at the latest. The SRU stresses the climate-political necessity of immediately starting the phase-out to achieve appropriate implementation of the Paris climate targets in Germany. Other studies reach similar conclusions. Depending on the ambition of the first stages of the phase-out, studies show that it is technically feasible to accomplish a coal phase-out by 2035[52] or as soon as 2030[53]. If the 1.5°C target of the Paris climate agreement is taken as the reference point, the phase-out of coal in Germany must however already occur by around 2025[54]. A different time horizon for the phase-out of coal was adopted by the G7 in 2015 who decided to end the use of fossil fuels by the end of the century[55]. Hence, reflecting these different scenarios, our choice experiment uses 2025, 2030, 2040 and 2100 as attribute levels.

Arguments about costs, the second attribute of our choice experiment, play a large role in the public debate around phasing out coal. During the negotiations for a government coalition consisting of the Christian Democrats (CDU/CSU), the Liberal Democrats (FDP) and the Green Party (the so-called "Jamaica coalition") in November 2017, a number of energy-intensive firms publicly warned that a phase-out of coal could mean electricity prices rising by up to 30 percent[56]. While the exact effect of reducing coal-fired power generation on the electricity market depends on a variety of factors, including demand response, growth in renewable power generation and cross-border trade, it seems plausible that changing the demand-supply balance could have an effect on prices. A study commissioned by the trade union ver.di indicates that an earlier phase-out would entail significant employment-related costs[57]. Various proposals for financing the phase-out of coal have been articulated, such as a levy on the electricity price or a structural transformation fund for the German coal regions[58]. To make the costs a relevant choice consideration for individual respondents, we made the assumption that they would be passed on to consumers. In the choice tasks, we presented the attribute as cost per household or overall cost to the economy, respectively, leaving open the concrete financing mechanism through which those costs would incur to consumers. In the instructions to the choice experiment, we mentioned electricity price increases as one such possibility, which does not preclude other financing mechanisms that would ultimately also affect consumers, e.g., CO_2 taxes or emissions trading. As existing investigations necessarily work with a number of assumptions, it is difficult to find clear reference points for plausible cost scenarios. The study by Ecke (2016), however, offers some guidance[57]. This study estimates that the annual cost of a phase-out until 2040 amount

to €499 million if industry and large customers were exempt from the corresponding levy. Projected onto electricity prices, this corresponds to €0.0014 per kilowatt hour (kWh), implying an annual electricity price increase of €4.20 for a typical 2-person household with a consumption of 3,000 kWh (p. 7). In order to leave space for other factors not taken into account in estimates made to date, we defined cost levels of €6, €12 and €18 (annual, per 2-person household). As a reference category, we assumed no costs.

The way cost of a coal phase-out is presented to respondents might influence the weight they assign to this attribute. To take the possibility of such cost framing effects into account, 50 percent of respondents (randomly assigned) received the same information in a different format. In addition to the electricity price increase per household, they were also informed about the corresponding overall costs for the economy. Projecting the costs per household onto the entire economy leads to cost levels of €250 million, €500 million and €750 million (see Table 1). As it turns out, however, the way the costs were presented in the choice experiment did not influence respondents' responses. Hence, for all analyses reported in the paper, we pooled the data of the respective subsamples.

Along with the timescale and the costs, employment effects are an important consideration in planning a coal phase out. More than 20,000 people are currently employed in the coal industry[51]. Nearly 70 percent of those working in the lignite mining sector are already over 46 years old and therefore reach retirement age in the mid-2030s. Taking existing early retirement programs into account, around 5,000 to 7,500 people remain for whom new perspectives would have to be found with a phase-out of coal by 2040 at the latest (ref. [51], p. 25). In case of an earlier phase-out, or if jobs only indirectly dependent on the coal industry are considered, this number rises.

To get a complete picture of the effects on employment, the number of newly-created jobs, especially in the renewable sector, must be considered along with the number of jobs lost[51]. According to the German government, 330,000 jobs had been created in the country's renewable energy sector by 2015[59]. Phasing out coal would likely not only lead to the creation of new jobs in the renewable sector, but also in other sectors of the economy. Moreover, after closure of the current open cast mines, jobs in restoring the destroyed landscapes will be created or remain in place for longer periods of time. Some studies therefore conclude that the net employment effects of phasing out coal could indeed be positive[51,60]. To account for both positive and negative employment effects, we included two separate attributes, ranging from 5,000 to 20,000 jobs each.

Finally, as evidenced by the final report of the German Coal Commission, a policy to phase out coal would need to entail specific measures for supporting the transformation of the regional economy. For example, such a policy might provide financing for early retirement and re-training programs for coal industry employees[51] and/or prioritize deployment of renewable energies in the coal regions. Other conceivable measures include investment in modern infrastructure (e.g. public transport, electric vehicles, digitalization), incentives for the creation of new businesses (e.g., start-up funding), and public investment in research and development. Opinion surveys[31] on phasing out coal have not investigated whether the

public has a pronounced preference for particular measures in supporting the structural transformation, and whether this attribute is more important than others.

Table 1 entails a summary of the policy attributes and levels. All attributes and their levels were briefly explained to study participants before the choice experiment started. The choice experiment itself consisted of eight successive rounds. In each round, participants were presented two policy scenarios for a phase-out of coal, in which the levels of attributes were randomly varied both within and across the binary comparisons. To prevent order effects, the order in which the attributes appeared in the description of scenarios was randomized across respondents but fixed for each respondent. At the end of each round, particiants had to evaluate the scenarios based on two different scales. First, they were asked to indicate which of the two scenarios they preferred (forced choice outcome). Second, participants were asked to provide a more detailed evaluation of the two scenarios, using a scale from 1 (“very poor”) to 7 (“very good”) (rating outcome).

Measurement of moderators

Party identification was measured based on the two-step approach used in the Socio-economic panel, which has been conducted since 1984 by the German Institute for Economic Research[61]. In a first step, respondents were asked whether they hold a preference for a specific party. If they replied in the affirmative (which was the case for 1,275 respondents or 64% of the main sample), they were then asked which of the seven parties represented in the Lower House of the German parliament they identify with, or whether they preferred another party.

To measure perceived scientific consensus, respondents were asked to indicate the percentage of climate scientists worldwide who think that the increased concentration of carbon dioxide in the atmosphere since the middle of the 20th century is primarily due to human activity. They could choose a percentage between 0 and 100% with a slider.

Strong ties with the coal industry were measured with two items, asking whether respondents themselves or someone they personally know works in a coal mine or a coal-fired power station, or has done so in the past.

Data analysis

The fully randomized design allows us to simultaneously estimate the causal effects of multiple treatment components based on simple linear regression[26]. Hence, AMCEs were calculated using an OLS regression estimator with standard errors clustered by respondent, using Stata 14.2. The dependent variable is based on the rating scale, and the models include sets of dummy variables for the values of all attribute levels.

To ease interpretation of the results, we dichotomized the data obtained with the rating scale using the median (which is 4) as cutoff value. The resulting variable *Phase-out Support* is hence coded 0 for cases where a respondent rated a proposal as poor to neutral (1 to 4) and 1 for cases where (s)he was (rather) positive about it. The rationale for using the rating outcome as dependent variable (instead of the forced choice outcome) is that it may allow for a more fine-grained assessment of preferences. In the first task (forced choice),

respondents had to choose one out of two scenarios in each of eight rounds. However, the comparison of scenarios may include instances where respondents have either strong preferences for or against both proposals – a situation that cannot be meaningfully ascertained by a force choice outcome. In the rating task, on the other hand, respondents could appraise both scenarios independently of each other, and on a more fine-grained scale. Nevertheless, replicating the analyses based on the forced choice outcome leads to substantively the same results (see Supplementary Figure 2).

Samples

The choice experiment was implemented in an online survey, which was fielded between December 2017 and January 2018. Study participants were drawn from the opt-in online consumer panel operated by Kantar/Lightspeed, which includes more than 230,000 registered individuals in Germany[62]. From this panel, a nonprobability but representative sample of 2,161 Germans entitled to vote at national elections was drawn based on an algorithm to match the census population as good as possible on age, gender and household income. Supplementary Table 1 shows that the sample matches the German population well in terms of age and gender. With regard to income, both low-income and high-income households are under-represented. However, given the fact that we also allowed respondents to provide no answer, the deviations appear to be relatively small overall.

The two additional regional samples for Rhineland (n = 533) and Lusatia (n = 501) were drawn from the same consumer panel. As the two coal regions do not by themselves constitute administrative units, the target population for each region was defined based on postal codes covering all towns and municipalities that border on the open-pit coal mines. The final lists include 53 postal codes for the Rhineland and 92 postal codes for Lusatia. It is difficult to assess the representativeness of the regional samples, as no data comprising the distribution of socio-demographic variables for exactly these regions are readily available. Compared to the German population as a whole, the two regional samples show some deviations with regard to gender and age. The distribution of income varies between both samples: while the Rhineland sample includes more high-income individuals than the German sample, the Lusatia sample includes higher shares of low-income individuals. This is in line with the different economic conditions between Western and Eastern Germany.

To identify random responders, we implemented a short attention test immediately after the choice experiment. All analyses shown in the paper are based solely upon the responses of all participants who passed this test. Hence, the final samples consist of 1,984 (Germany), 491 (Rhineland) and 473 (Lusatia) respondents (see Supplementary Table 1). As can be inferred from Supplementary Table 1, 247 participants failed to answer the attention test correctly across samples.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

The authors acknowledge support by the Andlinger Center for Energy and the Environment at Princeton University, the Swiss Center of Competence for Energy Research SCCER CREST, Swiss National Science Foundation (Grant no. P1SGP1_174939) and Greenpeace Germany, who funded data collection. Design of the research project and data analysis was the sole responsibility of the authors.

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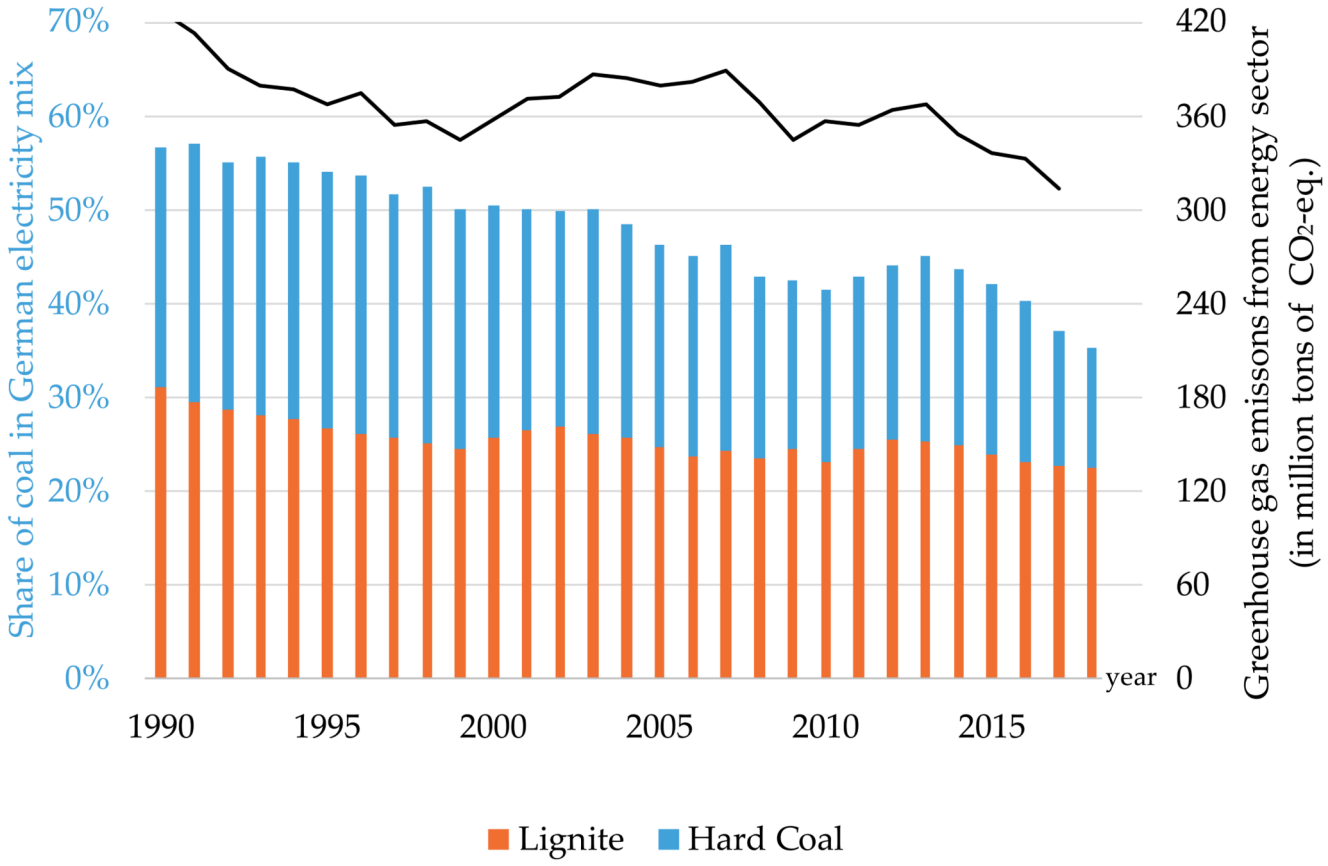

Figure 1. Share of coal in German electricity mix and energy-related greenhouse gas emissions 1990 - 2018.

Based on data from AG Energiebilanzen[18] and German Environment Agency[64].

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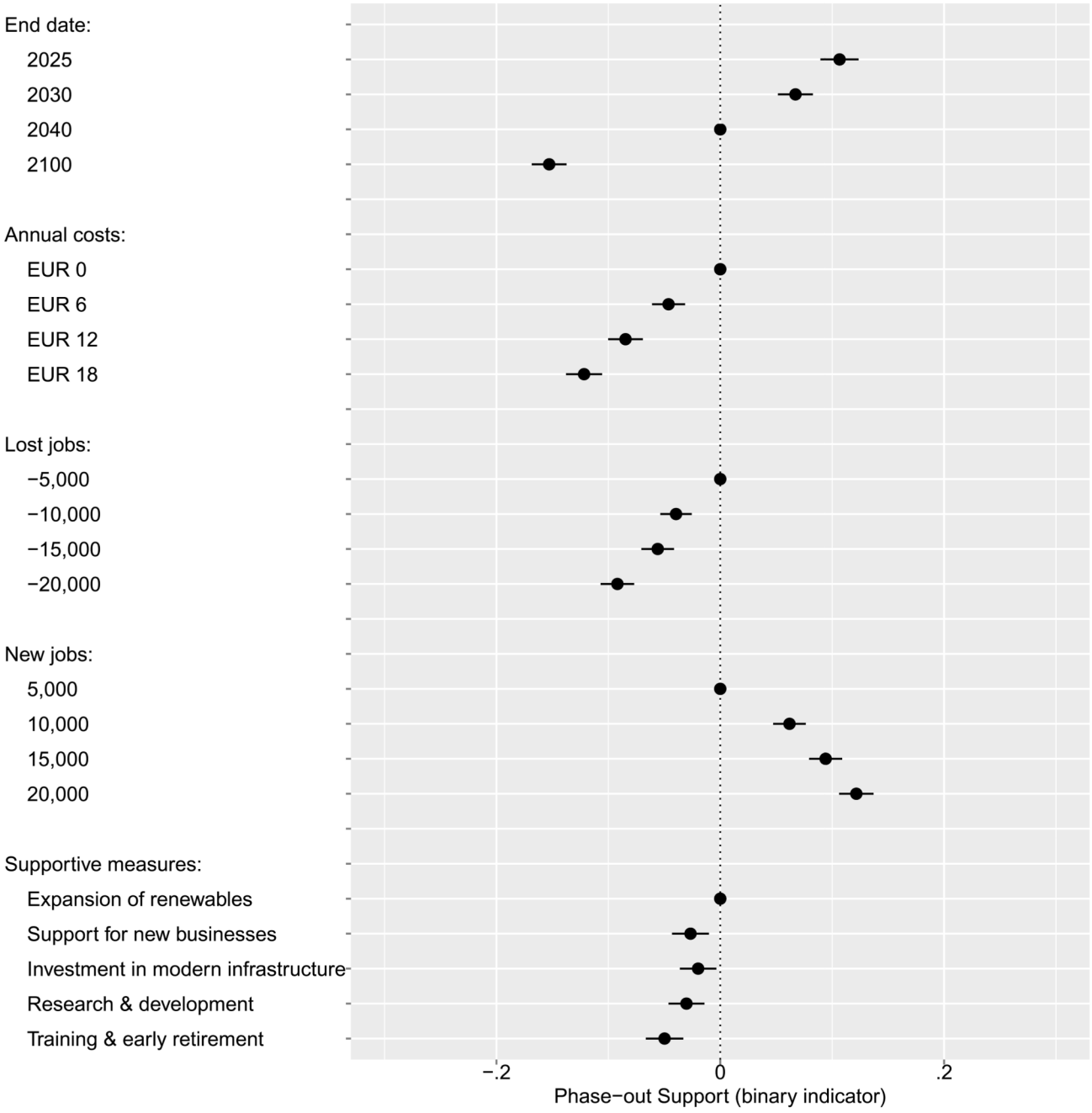

Figure 2. Average effects of policy attributes on respondents' preference for a coal phase-out.

Each dot represents an average marginal component effect (AMCE) of randomly assigned attribute levels on the probability of supporting a given policy scenario in relation to the reference scenario, all else being equal. The horizontal bars represent the 95% confidence intervals. Dots without bars represent the reference level for each policy attribute. n = 1,984 respondents / 31,744 policy scenarios.

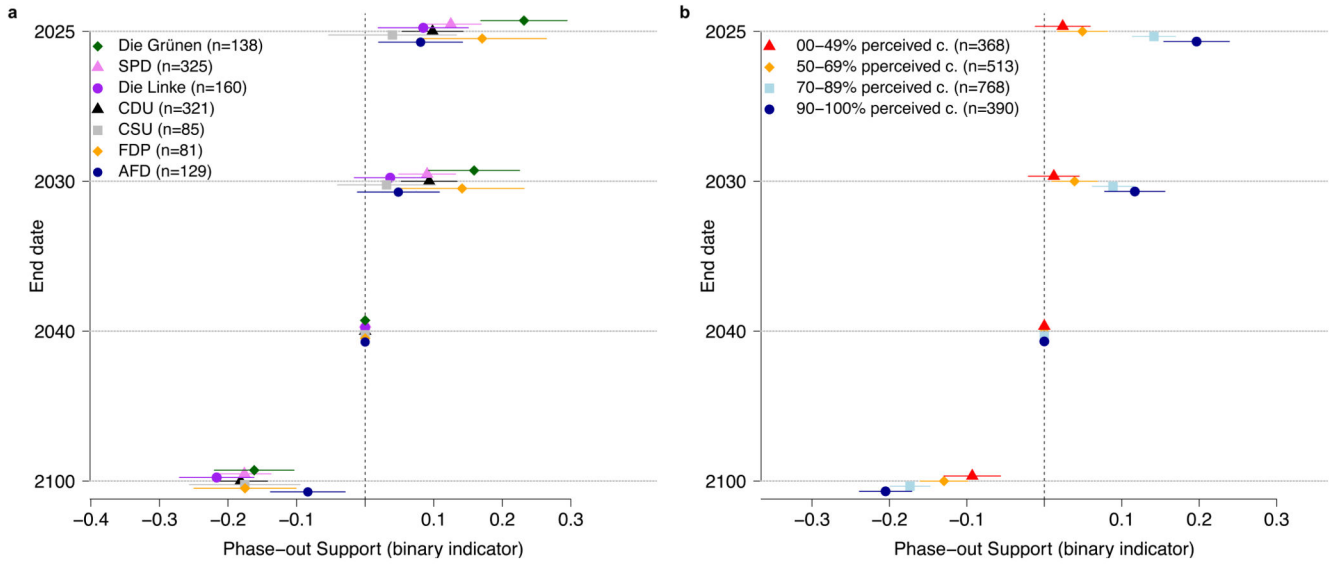

Figure 3. Average effects of timing attribute on respondents' preference for a coal phase-out.
Symbols represent AMCEs for the timing attribute (base 2040), conditional on (a) party identification and (b) perceived scientific consensus about the anthropogenic nature of current climate change. The horizontal bars represent the 95% confidence intervals.

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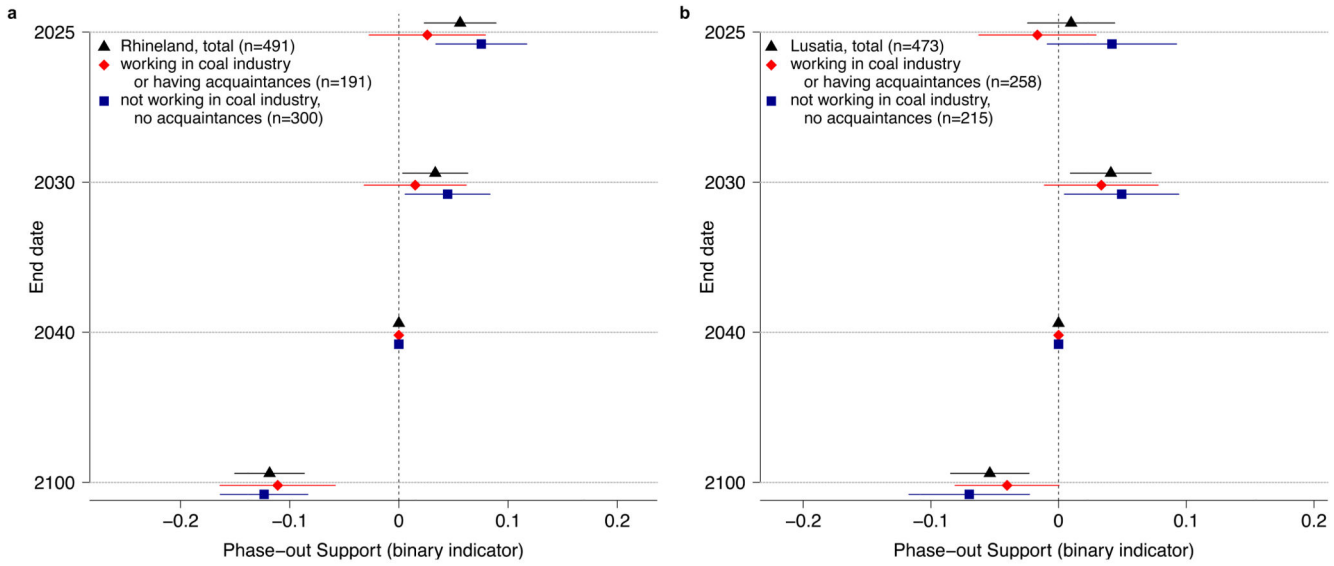

Figure 4. Average effects of timing attribute on respondents' preference for a coal phase-out in Rhineland and Lusatia.

Symbols represent AMCEs for the timing attribute (base 2040) for the (a) Rhineland and (b) Lusatia samples, excluding inattentive respondents. Additionally, the analyses differentiate between respondents employed by or with acquaintances in the coal industry (red) and those without strong coal industry ties (blue). The horizontal bars represent the 95% confidence intervals.

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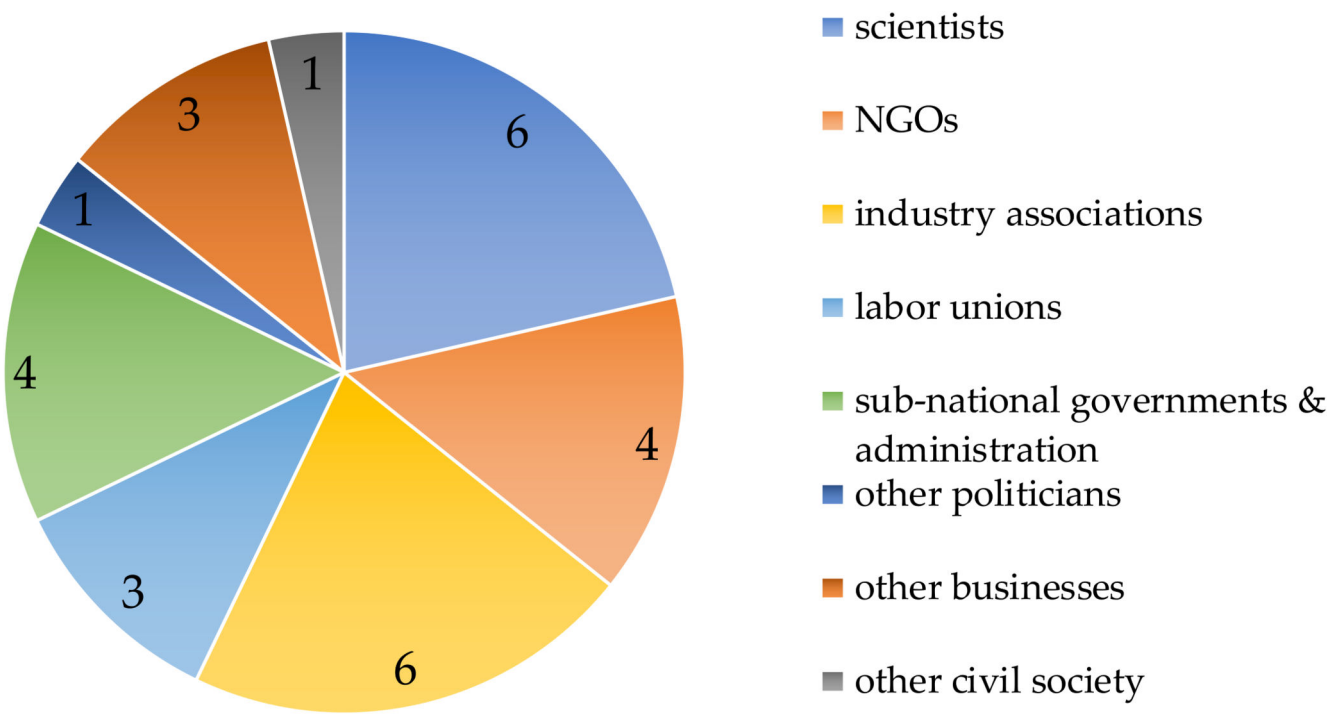

Figure 5. Composition of the Commission on Growth, Structural Change and Employment.
Numbers indicate number of members of the Coal Commission entitled to vote per category based on the list of commission members[24].

Table 1

Choice experiment design: policy attributes and levels

Policy attributes	Attribute levels
End date of the phase-out	• By 2025 • By 2030 • By 2040 • By 2100
Annual costs (per 2-person household) / (overall costs for the economy)	• €0 • €6 (€250 million) • €12 (€500 million) • €18 (€750 million)
Number of lost jobs in the coal industry	• − 5,000 • − 10,000 • − 15,000 • − 20,000
Number of newly created jobs	• 5,000 • 10,000 • 15,000 • 20,000
Measures for structural change	• Investment in expansion of renewable energies • Investment in regional funding programs for new businesses (e.g. start-up funding) • Investment in modern infrastructure (electric vehicles, digitalization) • Investment in research and development • Mixture of further training and early retirement of coal industry employees