An empirical exploration into the role of phase-out policies for low-carbon energy transitions: the case of the German *Energiewende*

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Abstract:

The energy sector plays a significant role in reaching the ambitious climate policy target of limiting the global temperature increase to well below 2°C. To this end, technological change has to be redirected and accelerated in the direction of zero-carbon solutions. Given the urgency and magnitude of the climate change challenge it has been argued that this calls for a policy mix which simultaneously supports low-carbon solutions and also deliberately drives the discontinuation of the established technological regime. Yet, the effect of such phase-out policies on the development and diffusion of low-carbon technologies has received little attention in empirical research so far. This paper addresses this gap by taking the case of the transition of the German electricity generation system towards renewable energies – the so-called Energiewende. Based on a survey of innovation activities of all German manufacturers and suppliers in renewable power generation technologies conducted in 2014 it explores the impact such destabilization policies – most prominently Germany's nuclear phase-out policy – may have on the development and diffusion of renewable energies. By drawing on descriptive statistics, factor and regression analysis the paper shows that Germany's nuclear phase-out policy had a positive influence on manufacturers' innovation expenditures for renewable energies. Somewhat surprisingly it was even seen as the by far most influential policy instrument for the further diffusion of renewable energies in Germany. The implications of these findings are discussed in light of ongoing debates on policies for accelerating the phase-out of coal to meet climate change targets.

Keywords: energy transition, policy mix, creative destruction, discontinuation/destabilization policy, credibility, renewable energy, nuclear energy

1. Introduction

The energy sector plays a significant role in reaching the ambitious climate policy target of limiting the global temperature increase to well below 2°C, as agreed at COP21 in Paris (UNFCCC 2015). To this end, technological change has to be redirected and accelerated in the direction of zero-carbon solutions which calls for a policy mix including demand pull, technology push and systemic instruments (Rogge & Reichardt 2016). In addition, policies aimed at the destabilization of the existing energy system have been argued to play a key role for such a transition (Kivimaa & Kern 2016). Yet, the effect of such destabilization policies on the development and diffusion of low-carbon alternatives has received limited attention in empirical research so far, particularly when it comes to phase-out policies.

In this paper I address this gap by taking the case of the transition of the German electricity generation system towards renewable energies – the so-called *Energiewende* (Strunz 2014; Agora Energiewende 2013). Its long-term target of reaching at least a level of 80% electricity generation by renewable energies by 2050 is supported through a rich instrument mix, which also includes destabilization policies –

most prominently the nuclear phase-out policy until 2022 (Morris & Pehnt 2014; BMWi; BMU 2010; BMWi 2016). Based on a survey of innovation activities of all German manufacturers and suppliers in renewable power generation technologies conducted within the GRETCHEN project this paper explores the impact of the nuclear phase-out policy on the development and diffusion of renewable energies.

In the remainder of the paper, I briefly summarize the literature on destabilization policies (section 2), and then describe the research case (section 3) and methodology (section 4). In the main part of the paper I present the results on the impact of the German nuclear phase-out policy on technological change in renewable energies (section 5) and close with a discussion of implications for the governance of the decarbonisation of energy systems (section 6).

2. Literature Review

Decarbonising the energy system is a key success factor for mitigating climate change (Vuuren et al. 2012). Yet, such a decarbonisation is faced with market failures in the form of negative externalities of GHG emissions and positive knowledge spillovers of low-carbon innovations. Given these double externalities this calls for a combination of policy instruments which address both market failures (Rennings 2000; Jaffe et al. 2005). How these instruments interact has been of great interest to academics and policy makers alike, particularly since the introduction of the EU ETS as market based climate policy instrument in 2005, intended to complement other policy instruments, such as feed-in tariffs (Sorrell & Sijm 2003; Schmidt et al. 2012; del Río González 2007). However, it has also been increasingly recognized that the low-carbon transformation of the locked-in energy system has to overcome additional institutional and system failures and barriers (Weber & Rohracher 2012; Unruh 2000; Lehmann 2012; Sorrell et al. 2004). As a consequence, scholars interested in sustainability transitions such as the decarbonisation of the energy system have called for a broader consideration of policy mixes (Rogge & Reichardt 2016). In particular, it has increasingly been pointed out that such policy mixes should not only include instruments promoting low-carbon solutions but that in addition such mixes also need to include instruments targeted at the destabilization of established regimes (Kivimaa & Kern 2016). That is, policy mixes should not only focus on the promotion of green niche innovations (Smith & Raven 2012) but also on 'flip sides' to innovation in the form of destabilization of technological regimes (Turnheim & Geels 2012; Turnheim & Geels 2013) and 'discontinuation' processes aimed at phasing out certain technological trajectories (Stegmaier et al. 2014; Johnstone & Stirling 2015).

As argued by Kivimaa and Kern, policy mixes for transitions ideally "include elements of 'creative destruction', involving both policies aiming for the 'creation' of new and for 'destabilising' the old." (Kivimaa & Kern 2016, p. 205). Four entry points for such destabilization policies impacting the 'motors of creative destruction' are identified: control policies (such as carbon trading), significant changes in regime rules (such as electricity market reform), reduced support for dominant regime technologies (such as reduced public funding for coal R&D), and changes in social networks as well as the replacement of key actors (such as the substitution of incumbents with new entrants in policy advisory councils). The focus of this paper lies on control policies which put pressure on the established regime – in the case of the energy system one which is characterized by large-scale, centralized electricity generation based on fossil fuels and nuclear energy. One way to accomplish this is to internalize the negative externalities associated with the emission of GHG emissions. For example, the EU ETS is a prime example in this regard, as it establishes a carbon price signal which can help leveling the playing field between carbon-intensive and low-carbon alternatives. [1] Another powerful option destabilizing the established regime through regulatory pressure is by banning or phasing-out certain technologies. One prime example in this regard is the nuclear phase-out policy adopted by Germany, or the announced phase-out of coal in the UK.

1 However, given the weakness of the price for EU allowances so far this control policy has not been able to put significant economic pressure on carbon-intensive technologies, so that low-carbon innovation efforts have been mainly driven by the broader policy mix rather than the EU ETS.

However, while there is ample evidence on the so far limited impact of the EU ETS as a market-based control policy on low-carbon innovation and diffusion (Rogge 2016), there is little empirical evidence on the impact of other destabilization policies, such as phasing out nuclear or coal, on technological change in competing low-carbon technologies. Therefore, in this paper I am examining the case of the German *Energiewende*, with a focus on the impact of its dedicated nuclear phase-out policy on the innovation and diffusion of renewable energies.

3. Research Case

For analyzing the impact of phase-out policies on technological change I use the case of the transition of the German electricity generation system towards renewable energies – the so-called *Energiewende* – with its target of reaching at least a level of 80% electricity generation by renewable energies by 2050 (BMWi; BMU 2010; Agora Energiewende 2013). This long-term target is supported through a rich instrument mix (BMWi 2016), with the core instrument being the Renewable Energy Sources Act (EEG).

Introduced in 2000 the EEG established, among others, technology-specific feed-in tariffs guaranteed over a period of 20 years. Based on extensive monitoring and evaluation the EEG has been regularly amended since then, leading to a number of policy changes, including the increase of expansion targets for renewable energies and updates of feed-in tariffs based on techno-economic improvements and deployment success. In addition, unexpectedly positive developments in solar PV between 2009-12 led to exceptional adjustments in the EEG, causing some turmoil and consolidation of the Germany PV industry (Hoppmann et al. 2014). The EEG reform of 2014 – also dubbed as EEG 2.0 – continued to implement the government's increased focus on cost-effectiveness. For example, technology specific expansion corridors were introduced, and pilots testing a system change from feed-in tariffs to auctions were initiated, using open space PV as first example. [2]

However, aside from the EEG also many complementary measures have been in place for a long time, such as public R&D support, KfW funding programs, or grid expansion measures (BMWi 2016). Together with the long-term targets and the EEG, this rich policy mix has stimulated rapid technological change in renewable power generation technologies (Rogge et al. 2015). This includes the emergence of a strong renewable energy industry which has created jobs and successfully exports its products and services abroad. Also, the renewable energy sector has been highly innovative, as measured by patent applications, scientific publications or new products and processes. Finally, the share of renewable based electricity generation has increased from less than 5% in 2000 to more than 33% in 2015, with faster diffusion rates than originally foreseen (BMWi 2014).

Yet, what makes the German *Energiewende* a truly ideal research case to study the impact of destabilization policies is that the German policy mix also includes destabilization policies. The most prominent one is Germany's nuclear phase-out policy until 2022 which was initially negotiated with incumbents by the Red-Green Schroeder government and adopted in 2002. After a short interlude in 2010/11 it was by and large reinstated by Merkel's conservative-liberal government in 2011 as a reaction to the Fukushima incident. Since then, the nuclear phase-out policy enjoys cross-party support, thereby sealing the fate of nuclear energy in Germany (Morris & Pehnt 2014; Johnstone & Stirling 2015). In addition, the EU Emission Trading System (EU ETS) represents another destabilization policy by putting a price tag on greenhouse gas (GHG) emissions of regulated sectors, including energy. However, given the large accumulat-

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2 The most recent changes of the EEG in 2016 have continued this policy paradigm change in German renewable energy policy by rolling out auctions as standard allocation mechanism across all technologies –with exceptions being in place for small players, such as households – and by putting a greater emphasis on remaining within the envisaged, rather conservative expansion corridors. Consequently, it has been argued that the government is favoring investments by incumbents and slowing down the *Energiewende* (Geels et al. 2016), despite the large majority of Germans favoring a faster transition towards renewables (BDEW 2016).

ed surplus of EU allowances this EU control policy and its impact has remained rather weak (Rogge 2016). Finally, the introduction of policies for phasing out coal and lignite has only started to be put on the political agenda prior to the COP21 negotiations at Paris in 2015. Yet, their implementation has been faced with significant resistance by industry, unions and regional policy makers, despite Germany's gap in achieving its 2020 GHG reduction target (DIW 2014). This political deadlock in overcoming the Energiewende *Paradoxon* of rising CO_2 emissions from high load factors of existing coal and lignite plants sheds some doubts on the political will of the German government for achieving its ambitions GHG reduction target of 40% by 2020 and 80% by 2050 ().

4. Methodology

In order to explore the impact of destabilization policies on the development and diffusion of renewable energies I draw on the results of a survey of innovation activities of German manufacturers and suppliers in renewable power generation technologies conducted within the GRETCHEN project. The innovation survey was conducted by telephone in the summer of 2014 and achieved a response rate of approximately 36% of all German companies active in the supply chain for manufacturing renewable power generation technologies (n=390). Most companies focus on producing components to manufacture final products for generating power (71%), while about a quarter offer products for generating power (24%) and the remaining 5% sell production plants. Approximately 70% of the companies are small and medium sized enterprises (SMEs). The sample includes both new entrants but also incumbent players having redirected their activities towards emerging green niche markets in solar PV, onshore wind, offshore wind, biomass and biogas, geothermal, wave and tidal and hydro power. Photovoltaics is the most common technology with 46.2% of the companies having it in their product portfolio, while biomass/-gas, onshore wind, offshore wind and hydropower rank in the middle. Two thirds of the companies are active in one technology only, with the others being active in two or more. To account for this and ensure technology-specific answers, the survey was carried out for one specific renewable energy. Therefore, more than half of the responses to questions on the policy mix and innovation concerned PV (37.2%), biogas (22.3%) and onshore wind (17.4%). Finally, in 2011-13 more than 80% of companies engaged in innovation activities in the analyzed renewable power generation technology in these three years, with 75% having introduced product innovations and 66% process innovations.

In this paper, I combine insights from descriptive statistics (Rogge 2015) as well as factor and regression analysis (Rogge & Schleich 2015; Rogge & Duetschke 2015) to explore the impact of the nuclear phase-out policy in technological change in renewable energies in Germany. More precisely, regarding the impact on innovation I complement the assessments of companies regarding the impact of various aspects of the policy mix (Rogge 2015) – including different German expansion targets and policy instruments, the credibility of the German policy mix and foreign demand-pull instruments – with more sophisticated analyses based on exploratory factor analysis and regression analysis. The methodological details of these analyses are reported in two separate papers, one using R&D innovation expenditures as dependent variable estimated by a bivariate Tobit model (Rogge & Schleich 2015) and the other explaining the independent variable of policy mix credibility through a linear regression (Rogge & Duetschke 2015). Therefore, what is novel in this paper is its explicit focus on explaining the impact of the nuclear phase-out policy on innovation and diffusion, which becomes possible by combining insights from these separate analyses. Regarding the impact on diffusion I rely on the direct assessments of companies regarding the expected impact of various policy instruments – Including three destabilization policies, among them the nuclear phase-out policy – on the future expansion of renewable energies (Rogge 2015).

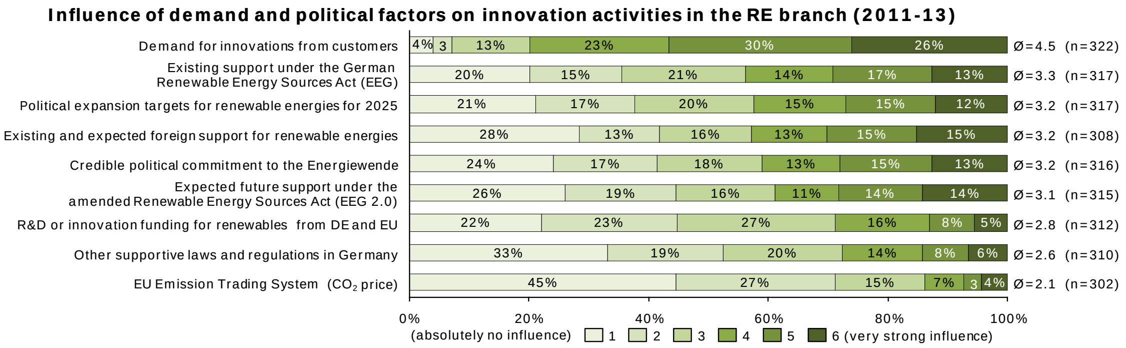
5. Results

In this section I start investigating the link between destabilization policies and technological change by first exploring the impact of the German nuclear phase-out policy on innovation, and then turn to its impact on diffusion.

Impact on innovation

Exploring the innovation impact of the German nuclear phase-out policy is not as straightforward an exercise, as this policy has not been included in a direct question on the link between policy and innovation, but only the EU ETS as another destabilization policy. More precisely, innovating manufactures were asked to assess the influence of different aspects of the policy mix for their innovation activities in the period 2011-13 (see Figure 2). The results show that domestic and foreign demand pull instruments are seen as most influential elements of the policy mix – both today's and expected future demand pull instruments – which is in line with findings of the eco-innovation literature (Horbach 2008; del Río González 2009; Peters et al. 2012; Hoppmann et al. 2013). However, the findings also show that the renewable expansion targets for the year 2025 and a credible commitment to the *Energiewende* is seen as almost equally important aspects of the policy mix. Interestingly, these demand pull instruments and the policy strategy with its long-term target were viewed as more important than German and EU R&D support for renewable energies – which had been received by roughly a quarter of respondents. As to be expected from earlier studies, the EU ETS was deemed as least relevant political factor for determining companies' innovation activities (Rogge 2016). Finally, to contrast the importance of political factors with the importance assigned to market factors companies were also asked about the influence of the demand for innovations from their customers, which by far was seen as most influential factor, thereby highlighting that in the supplier driven electricity sector the policy mix drives innovation by influencing demand (Rogge & Hoffmann 2010).

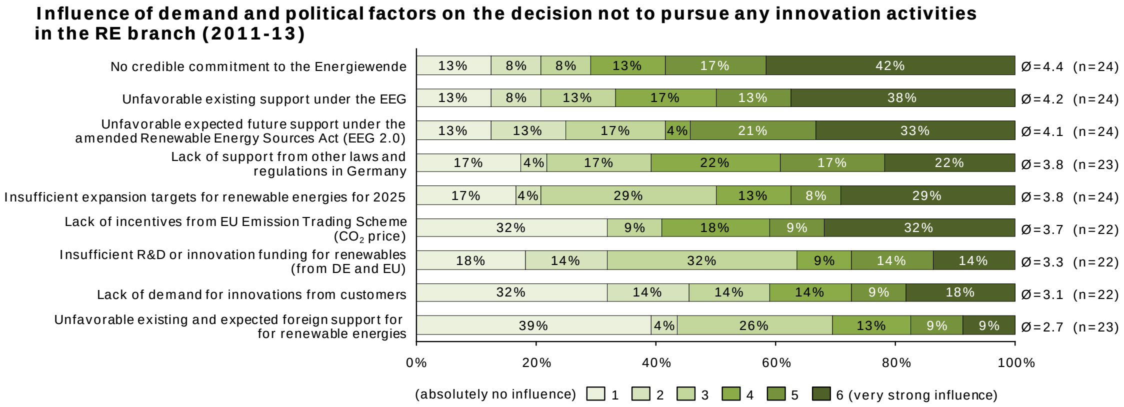
Figure 1: Company assessment of influence of policy mix on innovation (ranked by strength)



Source: Rogge (2015)

Manufactures who had no innovation activities in the period 2011-13 were asked a similar question about the influence of the above mentioned political factors on their decision not to pursue any innovation activities in renewable energies in that period. As can be seen in Figure 2, what non-innovators missed most was a credible political commitment to the *Energiewende*. They also criticized the insufficient support under the German Renewable Energy Sources Act (EEG). In contrast, the lack of demand for innovations from customers and unfavorable foreign support were seen as the lowest obstacles to innovation, while the lack of incentives from the EU ETS ranged in the middle field.

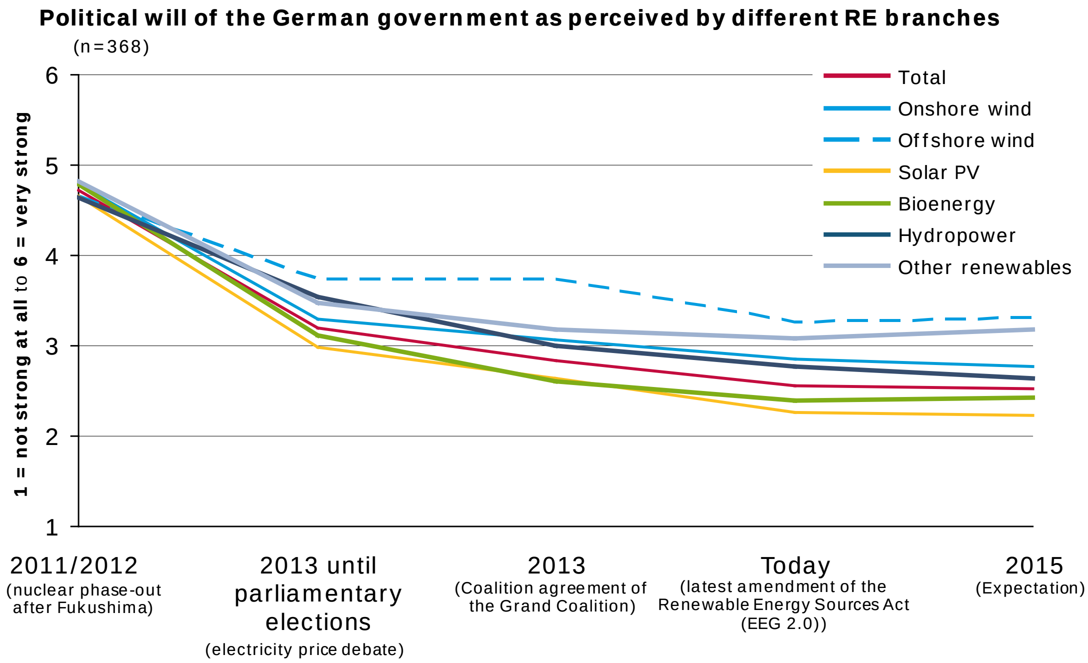
Figure 2: Company assessment of influence of policy mix on decision to not innovate



Source: Rogge (2015)

Given that a credible political commitment to the *Energiewende* (or perceived lack thereof) was among the top 2 most influential political factors in determining companies' innovation activities, in the following I will take a closer look at the development of this perceived policy mix credibility, and then will turn to its determinants – which will lead me to destabilization policies, and in particular to the nuclear phase-out policy. As can be seen in Figure 3, manufacturers were most keenly aware of the political will to promote power generation from renewable energies at the time of the nuclear phase-out reinstitution after Fukushima (2011/12). However, companies think this credibility of the policy mix supporting renewable energies has ebbed away since then. While there are distinct differences between technologies – with companies active in offshore wind viewing the political will most favorable, whereas manufactures in solar PV voiced serious doubts about the strength of the political will of the German government to promote the expansion of renewable energies – overall there is a sharply declining trend, which companies' expected to stabilize with the 2014 amendment of the EEG.

Figure 3: Perceived political will of German government regarding expansion of renewable energies



Source: Rogge (2015)

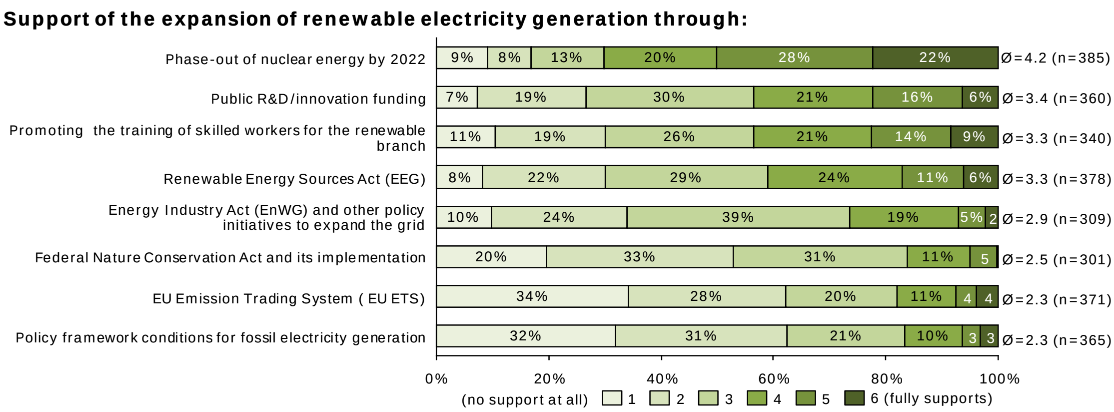
Given the indicated relevance of credibility for companies' innovation activities Rogge and Schleich (2015) included a variable measuring the perceived credibility of the policy mix in 2014 in their regression analysis using a bivariate Tobit model which simultaneously estimates companies' planned and expected innovation expenditures in 2014 and 2015. This credibility variable draws on companies' assessments of the extent to which the increase of electricity generation from renewable energies in Germany is supported by a broad consensus across all political parties, a clear political vision, a firm political will, unambiguous political signals and a strong support from the German government. This regression analysis, which also includes variables for technology push and demand pull instruments as well as other characteristics of the policy mix, such as its consistency, indicates that those companies which view the policy mix as more credible invest more in R&D in renewable energies.

Given that policy mix credibility seems to be a key determinant for companies' innovation activities and expenditures, Rogge and Dütschke (2015) investigate the reasons why companies belief (or not) in the policy mix, i.e. what determines the different perceptions about the strength of the political will of the German government in promoting the expansion of renewable energies. They find that, among others, not only the existence and design of the German feed-in tariffs for renewable energies determine the perceived credibility of the policy mix, but also other instruments, including the nuclear phase-out and the EU Emission Trading System. That is, destabilization policies are shown to positively contribute to companies' perceptions of the credibility of the policy mix, which in turn leads to higher investments in corporate R&D in renewable energies. This suggests an indirect link between destabilisation policies and low-carbon innovation which can be captured by measuring the credibility of the policy mix and its respective impact on innovation.

Impact on diffusion

After establishing that destabilisation policies such as the German nuclear phase-out policy and the EU ETS impact low-carbon innovation, I now turn to the question whether such control policies might also have an impact on the diffusion of renewable power generation technologies. To answer this question, I draw on the assessments of the surveyed companies regarding their support for the expansion of renewable electricity generation (see Figure 4). Accordingly, German-based manufacturers believe the nuclear phase-out offers the strongest support for the diffusion of renewable energies. In contrast, the EU Emissions Trading System hardly seems to have had any effect. The same holds for the framework conditions for fossil power generation technologies, where no specific phase-out policy was in place at the time of the survey.

Figure 4: Assessment of impact of policy instruments on diffusion of renewable energies



Source: Rogge (2015)

6. Conclusion

In this paper I have explored whether the German nuclear phase-out policy originally introduced in 2002 and – after a short interlude in 2010/11 – reinstated in 2011 has had an impact on innovation and diffusion of renewable power generation technologies. To answer this question I have drawn on insights gained from an innovation survey conducted among German manufacturers and suppliers in renewable power generation technologies. Contrary to what is typically expected I found that companies believe the nuclear phase-out offers the strongest support for the future diffusion of renewable energies. In contrast, the EU Emissions Trading System – another destabilization policy – hardly seems to have had any effect, which, given its low allowance prices, is hardly surprising and in line with previous studies. Manufactures also did not think that the framework conditions for fossil power generation technologies – which did not foresee any specific phase-out policy at the time of the survey in 2014 – have any significant positive impact on the future expansion of renewable energies. Should Germany eventually overcome the strong resistance of incumbents to implement a coal phase-out – as strongly suggested by think tanks and environmental NGOs (Graichen et al. 2016; DIW 2014), but only half-heartedly pursued by the Environmental and Economics Ministers –it seems likely that such a coal phase-out would – similarly to the nuclear phase-out policy – yield a positive impact on the diffusion of renewable energies.

Regarding the impact of the nuclear phase-out policy on innovation I find a positive link which seems to materialize through the effect of the existence of this policy on the overall credibility of the German policy mix for renewable energies. The findings suggest that manufacturers were most keenly aware of the political will to promote power generation from renewable energies at the time of the nuclear phase-out after Fukushima. However, companies think that this credibility of the policy mix has ebbed away since then. This is important as it is this credibility which was regarded by companies as almost as important a factor for determining their innovation activities as the German Renewable Energy Sources Act (EEG), the political expansion targets and foreign demand pull instruments, whereas the EU Emissions Trading System played hardly any role. Regression analysis indicates that those companies which view the policy mix as more credible invest more in R&D in renewable energies. Interestingly, not only the German feed-in tariffs for renewable energies determine the perceived credibility of the policy mix, but also other instruments, including the nuclear phase-out, but also the existence of the EU Emission Trading System. That is, destabilization policies are shown to positively contribute to companies' perceptions of the credibility of the overarching policy mix. And this, in turn, leads to higher investments in corporate R&D in renewable energies, therefore highlighting that the nuclear phase-out policy also had a positive innovation impact on these competing low-carbon technologies.

Policy implications

Based on these findings of a positive effect of the German nuclear phase-out policy on the development and diffusion of renewable energies I derive a set of key recommendations on how to tailor policy mixes in times of innovation and disruption which are currently occurring in the energy sector in transition. These policy implications are not only relevant to Germany but also to other countries, as all are faced with the challenge of decarbonising their electricity system until 2050.

First, policy makers should not underestimate the power of well-designed, ambitious destabilisation policies, such as stringent carbon prices or phase-out policies for coal, oil or nuclear. Destabilisation policies can significantly accelerate low-carbon technological change in low-carbon solutions– alongside their direct promotion – and should thus become a key constituent of future policy mixes of countries having signed the Paris Climate Agreement.

Second, our findings imply that doubling R&D funding for clean energy innovation will not be sufficient to achieve the COP21 decision on limiting climate change to well below 2°C. Rather, such a technology push approach must be part of a consistent policy mix which combines long-term targets for certain sectors and low-carbon technologies which go beyond 2020 with demand pull policies as well as destabilization policies.

Third, policy makers should pay greater attention to the perceived credibility of the overall policy mix, as this has a key influence on corporate R&D decisions in low-carbon technologies. In order to strengthen this credibility policy makers are well advised to underline their serious commitment to ambitious climate policy targets by implementing phase-out policies. For example, when a government goes forward in phasing out coal – despite strong resistance by affected incumbents – this is likely to be interpreted as strong signal and guide post for companies to invest in low-carbon technologies.

Fourth, governments can also enhance the credibility of their climate policy targets by strengthening the stringency of existing control policies. Above all, this concerns the EU ETS whose accumulated surplus allowances are limiting the destabilization effect of this policy instrument. That is, the positive effect of the EU ETS on policy mix credibility but also on innovation and diffusion is likely to be much stronger if the instrument had a more stringent design.

Methodological implications

Exploring the impact of destabilization policies on the innovation and diffusion of low-carbon alternatives requires their explicit consideration in a study's design, such as an energy innovation survey of companies. That is, to gain a broader understanding of the impact of phase-out policies future innovation surveys should strive to include them in their questionnaire design - not only regarding their impact on diffusion (as was done in the GRETCHEN survey) but also regarding their impact on innovation (which was not done directly in the GRETCHEN survey). The same logic applies to studies with other methodological approaches. For example, energy system models should explicitly include phase-out policies in one of their scenarios to increase our insights on the effects and interactions of phase-out policies with other aspects of the policy mix for decarbonising the energy system.

In conclusion, this paper has provided quantitative evidence gathered among German manufacturers of renewable power generation technologies showing that destabilisation policies in general and the German nuclear phase-out in particular can positively impact on technological change in renewable energies. As such, future policy efforts should pay much greater attention to devising feasible strategies for adopting such destabilisation policies despite the to be expected significant resistance of incumbents.

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