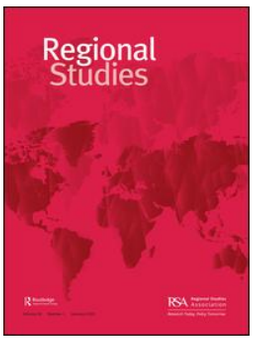

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Institutional relatedness and the emergence of renewable energy cooperatives in German districts

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ABSTRACT

This paper analyses the evolution of renewable energy cooperatives, examining all such cooperatives founded in German districts between 2006 and 2016. The rise of the cooperative form in renewable energy production is a prominent example of the strong involvement of users in market formation. We investigate the effects of 'institutional relatedness', arguing that renewable energy cooperatives can leverage the organizational knowledge and the legitimacy gained by cooperatives active in other industries in the same district. Using an organizational ecology approach, we find that the local presence of cooperatives in other industries indeed supported the founding of renewable energy cooperatives.

KEYWORDS

market formation; cooperatives; renewable energy; institutions; related diversification; legitimacy

JEL B52, L31, P13, R12

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INTRODUCTION

Geography of innovation tends to focus on spatial differences in new technology development by firms (Carlino & Kerr, 2015; Feldman & Kogler, 2010). The analysis of the diffusion of innovations – if analysed at all – is often reduced to spatial proxies of market size, thus neglecting the process of market formation across cities and regions. In market formation processes, users often play a pivotal role (Geels, 2004; Grabher et al., 2008; Malerba, 2002). This is especially relevant in the context of grand challenges faced by regions: to address challenges such as climate change and biodiversity loss does not so much require innovative activities by local firms but rather the large-scale adoption of sustainable technologies and practices by local users (Coenen et al., 2015; Truffer & Coenen, 2012). In order to adopt and embed new technologies in their local contexts, users may develop new organizational arrangements and actively lobby for favourable regulations (Garud & Karnøe, 2003).

We analyse the emergence of renewable energy (RE) cooperatives using data on all RE cooperatives entering in German districts between 2006 and 2016. The rise of RE cooperatives is a prominent example of the strong involvement of users – mainly households and farmers – in market formation, driven by environmental and political concerns regarding energy provision (Bauwens et al., 2016; Dewald & Truffer, 2011; Yildiz et al., 2015). Furthermore, RE cooperatives have been key actors in regional transitions to low-carbon energy supply, stimulating investments in RE production at the community level

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and contributing to the social acceptance of RE technologies due to their democratic and participatory features (Bauwens, 2016; Bauwens & Devine-Wright, 2018; Jobert et al., 2007). Their local embeddedness is of crucial importance because they often do not, or cannot, expand beyond local levels (Hufen & Koppenjan, 2015).

To understand local differences in the founding rates of RE cooperatives, we look at the supportive effects of 'institutional relatedness' within the district (Carvalho & Vale, 2018). We argue that cooperatives in the RE domain can leverage both the organizational knowledge and the legitimacy gained by cooperatives in other industries active in the same district. We also look specifically at the role of cooperatives banks in the same district in financially supporting the founding of new RE cooperatives (Ingram & Simons, 2000). To investigate legitimacy spillovers due to institutional relatedness, we make use of an ecological framework in which we analyse to what extent the cooperative activities in other industries in a district affect the founding of RE cooperatives, while controlling for other factors including climate conditions, election results, and national subsidy schemes.

Our paper contributes to current studies of regional development in three ways. First, adding to existing studies (Dewald & Truffer, 2012), we provide new insights in the remarkable growth in RE use in Germany by analysing the regional conditions that support the founding of RE cooperatives. Second, we show how one can use an ecological framework to investigate legitimacy spillovers stemming from institutional relatedness, while also controlling for supportive structures at the national level, further extending the regional applications of organizational ecology (Bigelow et al., 1997; Cattani et al., 2003; De Vaan et al., 2019; Wezel, 2005). Third, we enrich economic geography by showcasing the role of user cooperatives as agents of change and the role of institutions in this process. In doing so, we go beyond the firm-focus in economic geography by bringing back users into the analysis (Grabher et al., 2008) and take up the calls to better integrate institutional and evolutionary theorizing into a single framework (Binz et al., 2016; Coenen et al., 2017; Hassink et al., 2014).

The remainder of the paper is structured as follows. The next section outlines the theory on market formation for new technologies. The following section provides some background information on RE cooperatives in Germany. We then present the data and methods and continue with a discussion of the empirical results. We end with further reflections on the empirical study and the theoretical contributions to the field of economic geography.

THEORETICAL FRAMEWORK

Market formation and institutional relatedness

New technologies usually have difficulties to compete with established technologies as markets are initially lacking (Hekkert et al., 2007). While market formation is considered of key importance to the innovation process of emerging technologies, its driving forces are usually argued to be exogeneous. For RE technology, for example, the conditions for market formation are mostly explained with reference to favourable regulation and governmental support (Wüstenhagen & Bilharz, 2006). While such conditions play a pivotal role in the market formation of new technologies, it leaves one with the subsequent question why such favourable conditions emerged in some places rather than others (Dewald & Truffer, 2011; Moors et al., 2018). As Bergek et al. (2008) argued, closer attention should be paid to the identification of relevant actors, strategies and activities that hinder or facilitate market formation.

Some recent studies stressed the role of end-users in market formation (Dewald & Truffer, 2011, 2012; Meelen et al., 2019; Randelli & Rocchi, 2017). For our study, the papers by Dewald & Truffer (2011, 2012) are particularly relevant as they focused on the role of users in photovoltaic (PV) market formation in Germany specifically. Their main conclusion holds that the considerable regional differences in the deployment of PV markets cannot be attributed to geophysical conditions or incentive structures alone. They emphasize the important role of solar initiatives, as 'formalized networks comprising highly motivated (predominantly) private individuals, aiming at the support of renewable energies' (Dewald & Truffer, 2012, p. 409), setting up their own energy cooperatives to deploy PV and actively lobbying at local government for favourable regulation and support.

In the realm of RE more generally, citizen and farmer cooperatives have been pivotal in the development of solar energy, wind energy and bioenergy, leading to a proliferation of the cooperative form in in many countries (Bauwens et al., 2016; Boone & Özcan, 2014; Hewitt et al., 2019; Wierling et al., 2018). New market segments emerged through user initiatives organized in cooperatives, which started adopting RE technologies, and as such are central to the market formation. The nature of innovation here does not lie so much in the RE technology, but much more in the cooperative organizational form that users developed to align interests, pool resources and exchange user experiences. What is more, cooperatives are often founded on an ideological basis different from commercial corporations active in the same industry (Schneiberg et al., 2008).

As such, one can ask the question what regional conditions facilitate users in market formation. Following previous studies on market formation, we focus especially on the regional institutional conditions (Dewald & Truffer, 2012; Moors et al., 2018). The founding of a cooperative requires resources that are primarily locally drawn. Cooperatives need organizational knowledge and investment capital to be able to found their venture. However, given that their ways of organizing are new to the industry, they also depend on local legitimacy for the cooperative organizational model (Huybrechts & Mertens, 2014; Staber, 1989). In this paper, we argue that – as an organizational innovation – cooperatives can be expected to benefit from the local presence of cooperatives in other industries. Such legitimacy spillovers can be understood

as stemming from 'institutional relatedness' (Carvalho & Vale, 2018).

The institutional relatedness perspective as introduced by Carvalho and Vale (2018) in regional studies builds on the earlier notion of institutional relatedness in management studies, where it has been defined as 'the degree of informal embeddedness with the dominant institutions in the environment that confer resources and legitimacy (to organisations)' (Peng et al., 2005, p. 623). In regional contexts, the core tenet of institutional relatedness holds that organizations can leverage institutional capabilities present in other industries but in the same region, such as how to acquire licences, how to finance technology, how to set up new organizations, how to engage with policy makers, etc. Actors need all these capabilities to engage in a bricolage-type of development process involving not only learning by trial and error but also strategic collaboration among multiple actors to align technological, financial and political resources to support and legitimize new activities in a region (Binz et al., 2016; Carvalho & Vale, 2018; Garud & Karnøe, 2003).

In more general terms, the deployment of new technologies is facilitated by the mobilization of existing institutions to organize and legitimize a new practice, a process that has been called 'transposition' (Boxenbaum & Battilana, 2005; Powell et al., 2012). In this view of institutional relatedness, regions are more likely to adopt new organizational forms that are institutionally related to forms already present in the regions. In such regional contexts, actors can build, with modifications, on local institutional arrangements and practices. They may also face less local resistance as they draw on institutions that are considered legitimate in the local context (Content & Frenken, 2016; Padgett & Powell, 2012).

Following prior research on organizational forms, we distinguish cognitive and sociopolitical legitimacy (Aldrich & Fiol, 1994). Cognitive legitimacy refers to the spread of knowledge about an organizational form, where the highest level is achieved when a form is both well understood and taken for granted. This cognitive legitimacy is often argued to increase with a growth in the number of organizations in an industry, rendering an organizational form to become more familiar and less contested, and eventually mainstream (Hannan & Carroll, 1992; Staber, 1989). Thus, we can expect that the level of cognitive legitimacy rises with the number of RE cooperatives active within a particular region. Sociopolitical legitimacy refers to processes by which important stakeholders accept an organizational form as appropriate according to local norms and laws (Aldrich & Fiol, 1994).

Because the founding of a cooperative is heavily rooted in ideological motives of local individuals (Boone & Özcan, 2014; Schneiberg et al., 2008), we expect that they benefit from sociopolitical legitimacy of the organizational form. More specifically, the thesis we advance here holds that we expect RE cooperative foundings to benefit from the presence of local cooperatives active in other industries by building on the sociopolitical legitimacy that the cooperative organizational form has in those districts. This is based on the idea that organizations with similar ideologies and institutions can benefit from each other even if their core activity is unrelated (Barnett & Carroll, 1987; Greve & Rao, 2012). Besides direct support between these institutionally related organizations, regions with increased number of cooperatives in other industries will also have increased legitimacy with local governments, as prior cooperatives likely lobbied for regulatory and financial public support structures.

We further expect that founding a RE cooperative benefits from the presence of local cooperative banks. One the one hand, RE cooperatives are likely to benefit from the cognitive legitimacy carried by these cooperative banks, as they are very familiar with the organizational form. Furthermore, the cooperative form will also have more sociopolitical legitimacy in regions where more cooperative banks are located, as both are primarily oriented towards the interests of local communities. Thus, cooperative banks are likely to support cooperative foundings more directly than other banks, by acting as investor and advisor (Ingram & Simons, 2000). Indeed, Volz (2012) showed that in quite some cases, especially in the early phase of the solar cooperative boom in Germany, local cooperative banks initiated these RE cooperatives and have supported their management, creating a direct supportive link between the two.

To disentangle the different sources of legitimacy spillovers and the different spatial levels at which such spillovers may occur, we adopt an organizational ecology approach (Bigelow et al., 1997; Hannan et al., 1995; Wenting & Frenken, 2011). Our study fits into a small set of studies investigating the foundings of cooperative organizations in different industries (Boone & Özcan, 2014; Ingram & Simons, 2000; Lomi, 1995; Staber, 1989). Most prior studies in organizational ecology have argued that cognitive legitimacy spillovers mostly take place at broader geographical levels, while a more localized increase in the number of organizations will mostly have competitive impacts (Baum & Singh, 1994; Hannan et al., 1995). However, later findings suggest that both cognitive legitimation and competition effects are more prominent on the local scale (Greve, 2002; Lomi, 1995). While these studies focus on cognitive legitimacy, Wezel (2005) has argued that 'founding a new venture also requires the mobilization of various resources (e.g., human and physical capital, goodwill and normative support), [which] are unevenly distributed in space because subpopulations are characterized by different degrees of socio-political legitimation' (p. 732). As such, the spatial distribution of recourses of sociopolitical legitimacy are usually more complex and organization dependent (Baum & Oliver, 1996). This is why we also look at institutionally related industries – namely, the presence of cooperatives in other industries residing in the same region – thus distinguishing between legitimacy spillovers within the same industry and between related industries. We also look along the spatial dimensions, distinguishing between legitimacy spillovers among RE cooperatives within the

region, between neighbouring regions, and at the national level.

RE cooperatives

The tradition of cooperative organizations in the energy sector goes back to the late nineteenth century when people in rural areas in various countries (such as Germany, Denmark, Italy and the United States) set up 'electricity cooperatives' as a vehicle to invest jointly in infrastructure for rural electrification. Such investments not only concerned local distribution networks but also local energy production facilities ensuring a local supply of energy (Mori, 2014). Centralization and concentration tendencies in national energy sectors after the Second World War led to a decline of the number of cooperatives in national energy sectors. In Germany, for example, the number of electricity cooperatives dropped from approximately 6000 in the 1930s to about 40 in the 1990s (Holstenkamp, 2015). By the turn of the millennium, political decisions regarding deregulation, privatization and new legislation fostering RE led to a revival of cooperatives in the energy sector, with Germany being again one of the pioneering countries together with Denmark (Bauwens et al., 2016; Yildiz et al., 2015).

Common characteristics of RE cooperatives include (Bauwens, 2016, 2019; Huybrechts & Mertens, 2014): collective ownership by the majority of private individuals through the organizational and legal form of cooperative; an exclusive focus on activities in the RE sector; a broad scope including all fields of activity along the energy industry value chain (i.e., energy generation, energy distribution, energy trading, energy services); a common objective that the cooperative members share (e.g., supply with energy from renewable resources); and democratic voting mechanisms within the general assembly that assign a vote to a member irrespective of his share in the cooperative ('one member, one vote principle'). Furthermore, the use of the concept in practice is not only limited to private individuals but can also involve local utility companies and other stakeholders (Tarhan, 2015; Yildiz et al., 2015).

Most research on the determinants of the deployment of RE cooperatives has been qualitative so far (Bauwens et al., 2016; Kooij et al., 2018; Mignon & Rüdinger, 2016; Oteman et al., 2014). These studies pointed to two types of explanatory factors for the emergence of such initiatives: the regulatory environment and cultural factors. Regarding the influence of the regulatory environment, financial instruments and planning policies stand as the two main aspects (Bauwens et al., 2016). In particular, financial support instruments, such as feed-in tariffs, created low-risk investment conditions triggering a lot of investment, which proved more effective than other instruments such as premiums or tenders (Couture & Gagnon, 2010).

Regarding the influence of cultural factors, previous studies have pointed to the importance of environmental movements. In Germany, specifically, the origin of RE cooperatives is often linked with the presence of a strong culture of local energy activism and, in particular, the anti-nuclear movement (Beveridge & Kern, 2013). Furthermore, the extent to which a society is familiar with the cooperative model is said to have played a role. In countries where the cooperative movement has a historical and well-established tradition, people know about this legal structure and are aware of its benefits (and weaknesses). Hence, they are more likely to choose this juridical form when defining a RE project. Conversely, in countries where the general public and other actors are less familiar with this model, this low awareness may potentially constitute a 'cognitive barrier' (Huybrechts & Mertens, 2014). The supportive effect of familiarity with the cooperative model for the development of RE cooperatives is an example of a legitimacy spillover from institutionally related industries where cooperatives are already present.

DATA AND METHODS

Data

The sample for our study is taken from a database from Leuphana University's Department of Finance and Financial Institutions set up together with Jakob Müller (Degenhart et al., 2017; Kahla et al., 2017). From this database on German community energy companies, we obtain data on 1095 companies that were founded as registered cooperatives (eG), which, to the best of our knowledge covers all energy cooperatives registered until the end of 2016. For 1077 of these cooperatives, both the date of registration and the location are available, meaning that 18 cooperatives are excluded from our analysis. The vast majority of these cooperatives generate electricity from renewable sources and/or owns and operates heating grids fired by biomass. Therefore, we call them 'RE cooperatives'. This data set enables us to construct entry, exit and density variables for the German market for RE cooperatives. Following Staber (1989), we take the date of registration as a cooperative as founding date.

Figure 1 shows the entries, exits and total number of RE cooperatives in Germany for the most recent period of 2006–16, showing the rapid diffusion of RE cooperatives. To understand the sudden rise of RE cooperatives, three successive events are of importance. In 1998, the German government liberalized electricity markets. In 2000, it introduced feed-in tariffs with the Renewable Energy Sources Act (also known by the German abbreviation EEG). And in January 2006, the Cooperative Societies Act was amended reducing administrative burdens and decision-making costs, especially for smaller cooperatives. It is only after January 2006 that we witness a steep increase in the number of RE cooperatives. This rapid growth slowed down again a few years later, which relates to lower feed-in tariffs for RE following the amendments to the Renewable Energy Sources Act in January 2012 and August 2014.

Our analysis focuses on quarterly data during the 11-year period between January 2006 and December 2016, which coincides with the rapid diffusion of RE cooperatives following an 'S'-shaped curve consistent with the organizational ecology model (Figure 1). During this

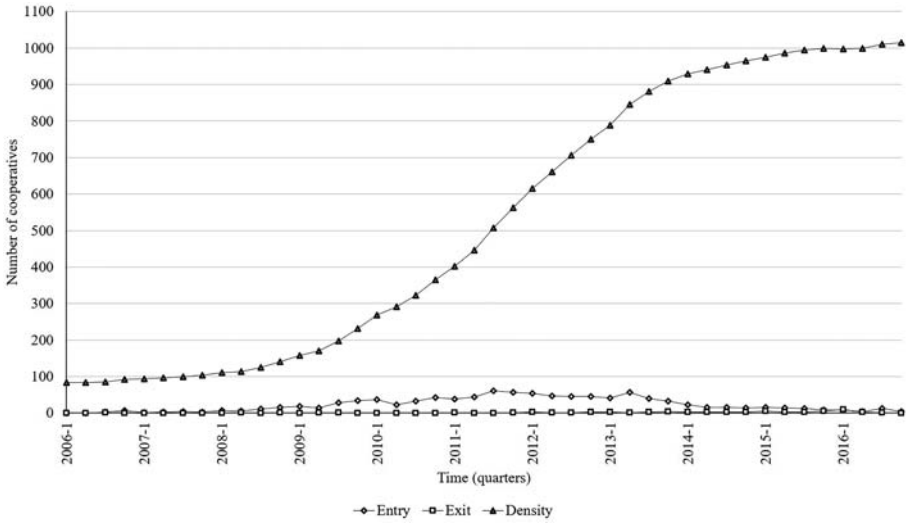

Figure 1. Renewable energy cooperatives population in Germany, 2006–16.

period, 993 cooperatives were founded, with 557 in solar technology, 152 in bioenergy, 78 in wind energy and 22 in other types of energy (for 184 cooperatives the specific energy type is unknown).

Figure 2 shows the local diffusion of RE cooperatives in Germany over time at the level of Germany's NUTS-3 districts (*Kreise*). We have taken the snapshots at the first quarter in 2006 and last quarter in 2016, and two dates in between corresponding with the dates of the major amendments to the Renewable Energy Sources Act at the national level. Figure 2 shows a higher concentration of RE cooperatives in southern Germany, while eastern German districts seem to have lower numbers of RE cooperative foundings, consistent with earlier research by Dewald and Truffer (2012).

Model

Organizational ecology studies the forces that shape populations of organizations over the long run (Hannan & Carroll, 1992; Hannan & Freeman, 1989). Organizational foundings within a specific market are understood as dependent on processes of legitimization and competition. The levels of legitimacy and competition are density dependent, meaning they are dependent on the number of organizations already present in the population. When a market is established, the founding of new organizations is positively dependent on density, because each existing organization provides legitimacy to the new market. However, when a market saturates founding will negatively depend on the density in this market because of increasing competition for resources. The two opposing effects are captured in an ecological model by a positive linear effect of legitimation and a negative quadratic effect of competition. Jointly, these effects lead to an 'S'-shaped curve. The founding rate is expressed as (Bigelow et al., 1997):

$$\lambda(t) = \exp(\beta_0 + \beta_1 N_t + \beta_2 N_t^2),$$

where $\lambda(t)$ stands for the founding rate measured in some time interval (here, quarters) and N_t represents the population density at time t (here, the number of RE cooperatives already present). In the ecological model, β_1 is expected to be positive indicative of the legitimation effect; and β_2 is expected to be negative indicative of the competition effect.

Rather than analysing the German population of cooperatives in its entirety, we take as the dependent variable the quarterly founding rate of RE cooperatives in each German district. In our analysis, we will look at the quarterly founding rate of all RE cooperatives as well as at the quarterly founding rate of solar energy, wind energy and bioenergy cooperatives, separately. As we count entries for 44 quarters and for 401 German districts, we have a total of 17,644 observations or 'spells'.

In order to analyse at what spatial level the processes of legitimization and competition take place, we extend the ecological model with density terms specified for the district and national level. In our study, we use Germany's 401 *kreise* (NUTS-3 level) to measure density at the district level, while density at the national level is measured by total national density (Bigelow et al., 1997; Wenting & Frenken, 2011). To account for spatial spillovers, we also include the densities of neighbouring districts to control for legitimation and competition effects of cooperatives present in neighbouring districts. This brings us to the baseline ecological model:

$$\lambda(t) = \exp\big(\beta_0 + \beta_1 n_{it} + \beta_2 n_{it}^2 + \beta_3 N_{it} + \beta_4 N_{it}^2 + \beta_5 \check{n}_{it} + \beta_6 \check{n}_{it}^2\big),$$

for each district i, where n_{it} represents the density of district i in quarter t; N_{it} is the density at the national level in quarter t; and $\check{n}_{it}$ is the sum of the densities of districts neighbouring to district i in quarter t. Note that to compute national density in quarter t, we take the national density minus the density of district i and the densities in the districts neighbouring district i.

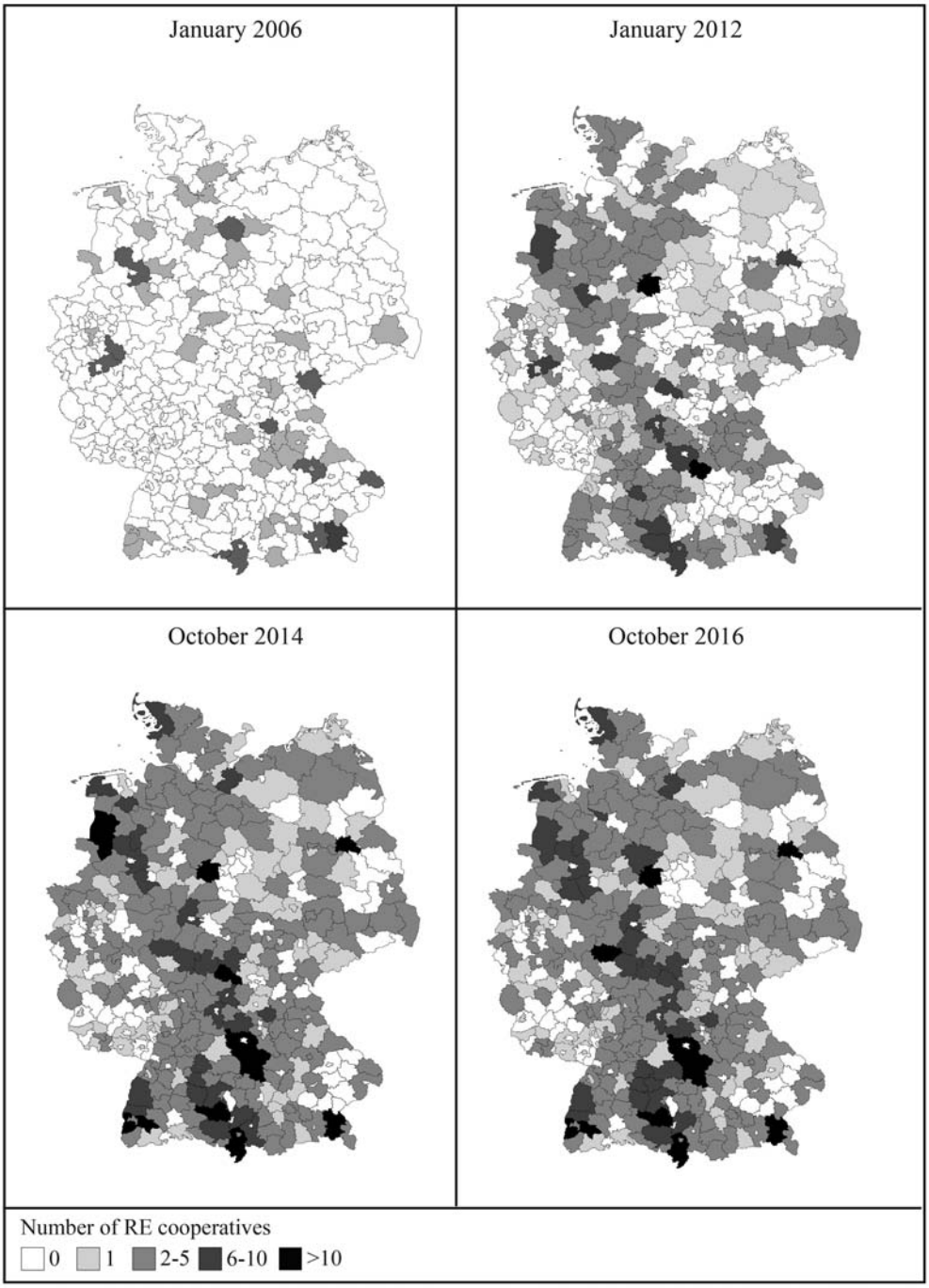

Figure 2. Spatial distribution of renewable energy cooperatives in Germany, 2006–16.

The model is further extended with institutional relatedness variables. We capture legitimacy spillovers from cooperatives in other industries using two variables of institutional relatedness. First, we measure the number of cooperative banks that are present in a district. This density variable is based on data from the National Association of German Cooperative Banks (Bundesverband der Deutschen Volksbanken und Raiffeisenbanken – BVR). We use the list of cooperative banks active in Germany that the BVR publishes yearly and used the number of banks that are present in a district at the beginning of that year.

Second, we seek to capture legitimacy effects of the cooperative organizational form in its temporal context (Ingram & Simons, 2000; Staber, 1989). In order to do so, we count the number of organizations with a cooperative legal form that are founded in a district in the last two years other than RE cooperatives. We use a founding measure instead of a density measure here because population dynamics (i.e., foundings and dissolvements) are generally believed to be more transitory than density-dependent measures (Delacroix et al., 1989; Hannan & Freeman, 1987), and as such capture better the temporality of acceptance and sociopolitical legitimacy of the

cooperative organizational form and its corresponding ideology. Put differently, by counting the foundings over the past years, we capture local 'momentum'. We choose a period of two years as we expect the process of founding a RE cooperative to take at most two years (see also Boone & Özcan, 2014). Using the Amadeus data set of Bureau van Dijk, we observe a total of 1833 cooperatives that are founded in Germany between 2004 and 2016 in all domains but excluding RE.

Finally, we include several control variables. First, we control for population density, GDP per capita and land area at the district level provided by Eurostat (2019a). National energy prices are included as a control variable to see to what extent foundings of RE cooperatives are driven by financial incentives, also taken from Eurostat (2019b) (as electricity prices for household consumers including all taxes and levies). Furthermore, we control for geophysical differences across districts using Deutscher Wetterdienst (DWD) data on solar irradiance and wind speed. We also include a time-varying control variable on the share of votes for the green party per district, during federal state election that are held (approximately) every four years, as a proxy for 'green attitudes' of the inhabitants of districts (Horbach & Rammer, 2018). And we use a dummy variable for districts in former Eastern Germany. As Bauwens et al. (2016, p. 142) noted, 'energy cooperatives are less developed in the Eastern part of Germany, owing to the socialist era's possibly negative legacy as well as to a financially worse-off population'.

Finally, we included a dummy variable for periods in between the main national policy changes discussed above. We used the two amendments of the Renewable Energy Sources Act in January 2012 and August 2014 to create three different policy periods: January 2006–December 2011, January 2012–September 2014 and October 2014–December 2016.

Regression

Organizational ecology models usually have dependent variables containing many zeros. Table 1 shows that in the distribution of our dependent variable 95% of the spells has no foundings of RE cooperatives. Furthermore, it shows that within the spells that do have at least one founding, 90% had only one founding in that district during that quarter. Because the cases with more than one founding are limited, and considering the large number of zeros in our model, we transform our data into binary data, as the main variation lies between zero and one founding (Barron & Hannan, 1991). We then use logistic regression to model the foundings of RE cooperatives. We estimate our regressions with the software package R, clustering observations by district and quarter to control for intra-district or intra-quarter correlation. Parameters are estimated using the maximum likelihood method.

RESULTS

Table 2 presents the descriptive statistics and correlations for our variables. The correlations between most variables are low to moderate, except where we would expect them to be high, as with the squared terms. Understandably, the policy period dummies correlate highly with national density. Therefore, we decided to include the policy period dummies only in a last model as robustness check.

Table 1. Distribution of the foundings of renewable energy (RE) cooperatives over our observations.

Number of foundings	Frequency	Percentage of spells	Percentage of spells with foundings
0	16758	94.98%	–
1	801	4.54%	90.41%
2	69	0.391%	7.79%
3	12	0.068%	1.35%
4	2	0.0113%	0.226%
5	2	0.0113%	0.226%
Total spells	17,644		
Total spells with foundings	886		

The results of our analysis are shown in Table 3. Model 1 only includes our control variables. Population density and GDP per capita show no significant effects. The effect for land area is positive and significant, indicating that the cooperatives are more likely to be founded in larger districts. Together with the negative significant effect of population density in later models, this suggests that RE cooperatives are founded where there is more land available. The energy price at the national level has a positive and significant effect, suggesting that when energy gets more expensive, people are more likely to found an energy cooperative. However, this effect does not seem to be robust in later models. Furthermore, the geophysical variables seem to have no significant effect on the founding of RE cooperatives in general. However, in later models wind speed does have a significant positive effect on the founding of cooperatives. Our dummy variable for Eastern German districts, as expected, shows a negative significant effect showing that cooperatives are less likely to be founded in these districts, in line with Bauwens et al. (2016). Finally, the share of votes going to the green party, as a proxy for green attitudes, has the expected positive effect on the likelihood of a RE cooperative being founded in that district, also in line with the qualitative analysis of Dewald and Truffer (2012).

In model 2 we include the density variables at the level of the district, neighbouring districts and the country as a whole. At the local level, only the legitimation effect is significant. The squared term of local density is insignificant, which suggests that the RE cooperatives do not compete with each other at the local level. The effects of density in neighbouring districts are insignificant, indicating that legitimacy spillover and competition effects between neighbouring districts are absent. Finally, for national density, we find the expected positive effect of the linear term and the negative effect of the quadratic term, in line with the 'S'-shaped

Table 2. Descriptive statistics and correlations.

	Variable	Mean	SD	Correlation																	
				(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1)	RE cooperative founding	0.05	0.22	1.00																		
(2)	Local density	1.26	2.17	0.14	1.00																	
(3)	(Local density^2)/100	0.06	0.25	0.12	0.85	1.00																
(4)	National density	517.20	377.94	0.03	0.41	0.22	1.00															
(5)	(National density^2)/100	4103.70	4296.77	0.00	0.40	0.22	0.98	1.00														
(6)	Neighbouring density	4.39	5.76	0.04	0.30	0.14	0.53	0.51	1.00													
(7)	(Neighbouring density^2)/100	0.52	1.42	0.02	0.22	0.10	0.34	0.34	0.88	1.00												
(8)	Local cooperatives foundations	0.73	1.45	0.28	0.45	0.42	0.14	0.11	0.10	0.05	1.00											
(9)	Local cooperative banks density	2.82	2.39	0.09	0.21	0.14	−0.07	−0.07	0.07	0.07	0.19	1.00										
(10)	Population density (in thousands/km^2)	0.52	0.68	−0.03	−0.07	0.00	0.00	0.00	0.00	−0.03	0.23	−0.15	1.00									
(11)	GDP per capita (in 10,000 euros)	3.14	1.39	−0.01	0.03	0.02	0.19	0.19	0.08	0.03	0.10	0.02	0.52	1.00								
(12)	Region area (km^2)	886.20	725.36	0.07	0.18	0.11	0.00	0.00	0.04	0.05	0.08	0.20	−0.53	−0.41	1.00							
(13)	National energy price (cents/kWh)	18.73	0.39	0.02	0.03	0.01	0.08	0.07	0.06	0.03	0.02	−0.04	−0.03	−0.01	0.02	1.00						
(14)	Solar irradiance (MW)	1.12	0.07	−0.01	−0.06	−0.02	−0.09	−0.10	−0.08	−0.06	−0.01	0.01	0.14	0.15	−0.27	0.02	1.00					
(15)	Windspeed (BFT)	2.12	0.57	0.00	−0.02	−0.03	0.00	0.00	−0.03	−0.05	0.01	−0.14	0.05	−0.13	0.15	0.06	−0.14	1.00				
(16)	Former East Germany region (dummy)	0.17		−0.01	−0.06	−0.02	0.00	0.00	−0.06	−0.04	0.04	−0.22	−0.08	−0.22	0.43	−0.02	−0.11	0.30	1.00			
(17)	Votes for Green Party (percentage points)	9.95	5.82	0.05	0.20	0.11	0.19	0.17	0.21	0.12	0.20	0.19	0.36	0.38	−0.27	−0.03	0.15	−0.12	−0.21	1.00		
(18)	Policy period 2006–12	0.55		−0.03	−0.39	−0.21	−0.93	−0.91	−0.48	−0.31	−0.14	0.07	−0.00	−0.17	−0.00	0.12	−0.00	−0.07	0.00	−0.18	1.00	
(19)	Policy period 2012–14	0.23		0.10	0.16	0.07	0.37	0.27	0.20	0.10	0.15	−0.03	0.00	0.06	0.00	−0.14	0.00	0.036	0.00	0.11	−0.59	1.00
(20)	Policy period post-2014	0.23		−0.06	0.30	0.18	0.73	0.81	0.37	0.27	0.01	−0.04	0.01	0.15	0.00	0.01	0.01	0.04	0.00	0.10	−0.59	−0.29

Table 3: Logistic regression models of renewable energy cooperative founding.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5	
Population density	0.022	(0.091)	0.040	(0.082)	−0.719***	(0.112)	−0.719***	(0.113)	−0.573***	(0.164)
GDP per capita	−0.029	(0.039)	−0.022	(0.040)	0.045	(0.040)	0.044	(0.040)	0.104	(0.071)
Region area	0.001***	(0.0001)	0.0004***	(0.0001)	0.0002*	(0.0001)	0.0002*	(0.0001)		
National energy price	0.136**	(0.047)	0.123*	(0.062)	0.101	(0.064)	0.102	(0.064)	3.065***	(0.443)
Solar irradiance	−0.021	(0.529)	−0.949*	(0.486)	−0.894	(0.527)	−1.042	(0.542)	−1.201	(0.807)
Windspeed	0.048	(0.070)	0.053	(0.072)	0.154*	(0.075)	0.152*	(0.075)	0.184	(0.101)
Former East Germany region	−0.644***	(0.134)	−0.441***	(0.130)	−0.454**	(0.142)	−0.454**	(0.142)		
Votes for Green Party	0.046***	(0.006)	0.023***	(0.007)	0.015*	(0.007)	0.015*	(0.007)	0.011	(0.012)
Local density			0.187***	(0.031)	−0.033	(0.040)	−0.031	(0.040)	−0.613***	(0.059)
(Local density^2)/100			−0.141	(0.204)	0.121	(0.284)	0.113	(0.283)	0.243	(0.333)
National density			0.010***	(0.001)	0.008***	(0.001)	0.009***	(0.001)	0.011***	(0.001)
(National density^2)/100			−0.001***	(0.0004)	−0.001***	(0.0004)	−0.001***	(0.0001)	−0.0001***	(0.0001)
Neighbouring density			0.004	(0.015)	0.024	(0.015)	0.023	(0.015)	0.029	(0.021)
(Neighbouring density^2)/100			−0.028	(0.060)	−0.054	(0.054)	−0.051	(0.053)	−0.072	(0.073)
Local cooperatives foundations					0.439***	(0.032)	0.439***	(0.033)	0.575***	(0.042)
Local cooperative banks density					0.044**	(0.017)	0.044**	(0.017)	0.150***	(0.028)
Policy period 2012–14							−0.239	(0.160)	−0.153	(0.155)
Policy period post-2014							−0.207	(0.294)	−0.109	(0.283)
District dummy	No		No		No		No		Yes	
Intercept	−6.456***	(1.023)	−6.828***	(−1.235)	−6.431***	(−1.290)	−6.377***	(1.286)	−62.863***	(8.375)
Log-likelihood	−3418.15***		−3104.26***		−2903.362***		−2902.032		−2556.099***	

Notes: $N = 17{,}644$; ***$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$ (all two-tailed).
Standard errors shown in parentheses are robust standard errors clustered by quarter and NUTS-3 region.

diffusion curve in Figure 1 showing an overall saturation in the population growth of RE cooperatives in Germany.

In model 3, we introduce the two institutional relatedness variables. The number of cooperatives founded during the past two years shows a positive and significant effect. This shows that the past foundings of cooperatives in any local industry in a district render the foundings of RE cooperatives in this district more likely. Model 3 also shows a positive and significant effect for the presence of cooperative banks on the founding of RE cooperatives in a district. When we compare these two effects, the founding of any cooperative (0.44) seems considerably stronger than the effect of the presence of a cooperative bank (0.04). This suggests that the legitimacy spillover from institutional relatedness comes primarily from the recent foundings of cooperatives in any local industry, rather than from the presence of cooperative banks. Importantly, comparing model 3 with model 2, the effect of local density of RE cooperatives turns insignificant. This indicates that legitimacy spillovers do not stem from the local presence of other RE cooperatives, but from institutional relatedness to recent foundings of cooperatives in other industries.

As a robustness check, model 4 adds the dummy variables for policy periods. The policy period variables do not have any significant effect while effect sizes and

Table 4. Logistic regression models of renewable energy cooperative founding separated by renewable energy type.

	Model 6			Model 7		
Variable	**Solar**	**Wind**	**Bio**	**Solar**	**Wind**	**Bio**
Population density	0.071	0.312	0.073	−0.555***	−0.257	−1.020***
	(0.106)	(0.288)	(0.197)	(0.142)	(0.286)	(0.286)
GDP per capita	−0.022	−0.258*	−0.094	0.007	−0.205	0.057
	(0.054)	(0.125)	(0.098)	(0.058)	(0.121)	(0.083)
Region area	0.0004***	0.001**	0.0004***	0.0001	0.001**	0.000*
	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0003)	(0.0001)
National energy price	0.154*	−0.117	−0.059	0.155*	−0.185	−0.095
	(0.073)	(0.060)	(0.051)	(0.072)	(0.064)	(0.053)
Solar irradiance	−1.758**			−2.200**		
	(0.616)			(0.675)		
Windspeed		−0.701**			−0.640**	
		(0.245)			(0.239)	
Former East Germany region	−0.896***	−1.119*	−0.256	−0.855***	−1.240*	−0.475
	(0.194)	(0.556)	(0.271)	(0.211)	(0.557)	(0.321)
Votes for Green Party	0.034***	0.016	0.004	0.029**	0.008	0.012
	(0.008)	(0.019)	(0.004)	(0.009)	(0.021)	(0.017)
Focal RE local density	0.255***	0.631	0.646**	−0.108	0.327	0.334
	(0.071)	(0.374)	(0.228)	(0.084)	(0.428)	(0.249)
(Focal RE local density^2)/100	−1.827	−3.605	−5.591	0.207	0.684	−4.629
	(0.937)	(4.483)	(5.588)	(1.220)	(5.167)	(6.65)
Other RE local density	0.052	0.272*	0.429***	−0.112	0.129	0.146
	(0.056)	(0.123)	(0.115)	(0.076)	(0.144)	(0.127)
(Other RE local density^2)/100	0.181	−2.671	−2.889*	−0.280	−3.356*	−1.847
	(0.527)	(1.385)	(1.308)	(0.891)	(1.329)	(1.465)
Focal RE national density	0.016***	0.208***	0.056***	0.015***	0.195***	0.043***
	(0.001)	(0.045)	(0.011)	(0.001)	(0.046)	(0.011)
(Focal RE national density^2)/100	−0.003***	−0.198***	−0.035***	−0.003***	−0.183***	−0.028***
	(0.0002)	(0.040)	(0.007)	(0.0002)	(0.041)	(−0.028)
Local cooperatives foundations				0.372***	0.323***	0.352***
				(0.036)	(0.061)	(0.047)
Local cooperative banks density				0.086***	0.011	−0.054
				(0.021)	(0.053)	(0.04)
Policy period 2012–14	−0.147	−0.944	0.324	−0.094	−0.683	0.355
	(0.181)	(0.738)	(0.395)	(0.196)	(0.746)	(0.416)

(*Continued*)

Table 4. Continued.

Variable	Model 6			Model 7		
	Solar	Wind	Bio	Solar	Wind	Bio
Policy period post 2014	−0.823*	−17.000***	−0.917	−0.537	−16.603***	−0.683
	(0.374)	(0.740)	(0.884)	(0.392)	(0.750)	(0.912)
Intercept	−6.321***	−4.991***	−5.740***	−5.740***	−3.661***	−4.569***
	(1.472)	(0.881)	(0.876)	(1.473)	(1.032)	(0.911)
Log-likelihood	−2029.4***	−388***	−722.5***	−1945.2***	−376.9***	−691.2***

Notes: $N = 17{,}644$; ***$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$ (all two-tailed).
Standard errors shown in parentheses are robust standard errors clustered by quarter and NUTS-3 region.

significance levels of the other variables remain largely unaffected. The results found in model 3 therefore seem to be robust. Finally, model 5 adds a district dummy to control for unobserved differences between districts that have fixed effects over time. Hence, this model does not include time-invariant variables on the district level (i.e., region area and former East Germany region dummy). Our main variables on institutional relatedness show to be robust in this model and even increase in effect size compared to model 4. Local density shows a negative effect, which only emphasizes that legitimacy spillovers do not stem from the presence of other RE cooperatives and seems to suggest that they might even compete at the local level.

Next, in Table 4 we report on the regression analysis for solar energy, wind energy and bioenergy cooperatives separately. Model 6 includes the control variables and the density variables at the local and national level, while model 7 introduces our variables on institutional relatedness. As we focus in each regression on one particular type of RE cooperative, we can now also include the local density effects of the other two types of RE cooperatives, as to test for legitimacy and competition effects between RE options. At the national level, the densities of the different types of RE cooperatives all showed a correlation higher than 0.9 and are therefore excluded from the analysis.

The results in Table 4 show that the effects of the control variables are similar to the results in Table 3 for all RE cooperatives. What is striking, though, is that energy price and green party votes only seem to affect the founding of solar energy cooperatives. As such, the effects of these variables found in our general model seem mostly driven by the foundings of solar energy cooperatives. An unexpected finding is that the geophysical variables in our analysis show the opposite effect of what we would expect. Local solar irradiance shows a negative effect on the founding of solar energy cooperatives and the wind speed shows a negative effect on the founding of wind energy cooperatives. This may indicate that RE production in such regions is dominated by for-profit firms looking for the best geophysical conditions for large-scale production. The result further speaks to the conclusion drawn by Dewald and Truffer (2012) that the concentration of solar energy cooperatives in Southern Germany should not be attributed to geophysical conditions, but to local citizen and farmer movements.

When turning to our main variables of interest in Table 4 and looking at model 6 and model 7, we observe similar effects as before. Only at the national level, the legitimation and competition effects are consistently significant and with the expected signs. Furthermore, as in the full model reported in model 7, we find that past foundings of cooperatives in other industries has strong positive and significant effects for all our three types of energy. However, the variable on the presence of cooperative banks is only significant for solar energy cooperative foundings. The latter result seems to suggest cooperative banks preferentially invest in solar energy projects, possibly because the small size of these projects entails lower risks. Cooperative banks, then, could use the community solar cooperative model to offer a low-risk investment to their customers.

Finally, the Appendix A in the supplemental data online tests whether these findings are robust by including a district dummy. The results in Appendix A show that our main variables on institutional relatedness do not change sign and significance compared with model 7.

DISCUSSION AND CONCLUSIONS

Our study analysed the evolution of RE cooperatives in Germany looking at all foundings between 2006 and 2016 at the district level. We were particularly interested in the effects of 'institutional relatedness' as we expected that RE cooperatives can leverage both the organizational knowledge and the legitimacy gained by cooperatives in other industries active in the same district. Using an organizational ecology approach, we found indeed that recent foundings of cooperatives in other local industries supported the founding of RE cooperatives in that district. We further found a positive effect of the presence of cooperative banks, more specifically, on the foundings of solar energy cooperatives.

Our results further showed that the national stock of existing RE cooperatives had a legitimizing effect on new foundings. The positive effect of national density aligns with prior studies distinguishing a local and a global level (Bigelow et al., 1997; Hannan et al., 1995). More generally, we understand the national process fostering legitimacy as the increased cognitive taken-for-grantedness of RE cooperatives (Hannan & Carroll, 1992; Pólos et al., 2002). When the number of RE cooperatives increases nationally, this cognitive legitimation means

that more entrants are likely to copy the business model of their predecessors, rather than trying something new (Aldrich & Fiol, 1994).

However, at the local level, the legitimization process takes on a different form. Here, the positive effect of RE cooperative density disappears when our variables on institutional relatedness are added. Both of our variables on institutional relatedness have a positive effect on RE cooperative founding, indicating a different legitimation process at the local level. In our interpretation, the local number of cooperatives that are founded in the last two years in any industry points to a sociopolitical form of legitimacy. This type of legitimacy refers to the value placed on an activity by cultural norms and expectations, where key stakeholders or audiences accept the business model as appropriate or desirable (Aldrich & Fiol, 1994). Indeed, our variable for cooperative founding captures the very temporal social settings of a district in which RE cooperatives are founded (Johnson & Powell, 2017). Even though these cooperatives are operating in different industries, they still have overlapping identities since most foundings of cooperatives are rooted in institutional repertoires and ideological motives of local communities at particular moments in time (Boone & Özcan, 2014; Schneiberg et al., 2008). As such, when local entrepreneurs are founding cooperatives in other industries, this is reflecting the presence of a support environment for the cooperative ideology (Ingram & Simons, 2000; Staber, 1989), which is much more of a sociopolitical form of legitimacy than a cognitive form of legitimacy.

The effect found for local cooperative bank density also underscores the idea that sociopolitical processes of legitimization are taking place primarily locally. A previous study already showed the supportive role that cooperative banks play for populations that share their ideology (Ingram & Simons, 2000). While cooperative banks on the one hand directly support and invest in RE cooperatives, the positive effect of the presence of cooperative banks on foundings of RE cooperatives also captures cognitive legitimacy spillovers, as cooperative banks are obviously familiar with the organizational and legal details of the cooperative form. The ideological interpretation of the two institutional relatedness variables is supported by the drop in the effect of the share of votes for the green party – as the only explicit ideological variable in the model – once the institutional relatedness variables are included. In sum, we understand the legitimization process of RE cooperatives as a combined process of increasing cognitive familiarity at the national level and increasing sociopolitical support at local levels.

While our study controls for policy periods, one could argue that national-scale regulations played a role in sociopolitical legitimization on the national scale. While the effects of detailed regulatory changes are beyond the scope of our study, it has been argued that the most important sociopolitical changes on a national scale date from before 2006, the start date of our study's time frame. Observers argue that this has been achieved in at least three ways (Blome-Drees et al., 2016): the change in cooperative laws increased the attractiveness of the legal structure; regional cooperative associations accompanied regulatory changes with intensified marketing campaigns to free the registered cooperative from its 'old-fashioned' image; and the financial crisis led to a rethinking of the way the economy works and led to growing interest in alternative forms of doing business. Future research could study the influence of national and regional regulatory changes and the influence of institutionally related firms or industries simultaneously to better differentiate their effects on levels of sociopolitical legitimacy.

With our study, we attempted to widen current research on market formation in two ways. First, we highlighted the key role that technology users can play in market formation processes and how this related to regional differences. Here, new markets are created through local users adopting new technologies and hereby contributing to the market formation for RE technologies. The innovation, in this context, does not lie so much in the RE technology, but in the cooperative organizational form that enables users to align interests and pool resources. Second, we argued that market formation processes can be supported by 'transposition': the mobilization and adaptation of existing institutions to organize and legitimize a new practice in another field (Boxenbaum & Battilana, 2005; Powell et al., 2012). Local actors who apply existing institutions in new contexts benefit from learning and legitimacy spillovers stemming from the institutional relatedness between existing activities and new activities (Carvalho & Vale, 2018).

Our emphasis on the role of technology users and institutional relatedness may also bear lessons for local and regional policy. One may argue that a too strong focus on leveraging technological capabilities for innovative activities by local firms may obscure the opportunities for local and regional development stemming from technology adoption (Tanner, 2014). Our study shows that users – here, consumers and farmers – can contribute to the process of regional diversification in two ways. First, to the extent that users deploy technology for household and farm production instead of importing energy from other regions, they contribute to a region's diversification and self-sufficiency, lessening a region's dependence on imports from other regions. Second, to the extent that users deploy new technology beyond household production and sell surplus production to other parties, they also add to productive activities in a region raising regional valued added (Kosfeld & Gückelhorn, 2012). As our study further exemplifies, the process of diversifying a local economic structure may be in large part a process of adoption of technologies from other regions, while building on local institutions (Boschma et al., 2017). In this sense, we also show how the established theory of regional diversification based on technological relatedness (Boschma, 2017) can be supplemented by institutional analysis, where new productive activities benefit more from institutional relatedness rather than technological relatedness (Carvalho & Vale, 2018).

Effective adoption of new technologies goes hand in hand with the adoption of complementary institutions that render such technology effective and affordable (Gertler, 2003). The policy lesson holds that for technology adoption programmes to be effective in a particular industry, appropriate institutional changes have to be made, which can be purposefully built on institutions already present in other industries. The application of existing institutions into new contexts, however, will generally prove difficult for the actors involved. Here, the government can play a key role in supporting actors to learn how existing institutions can be introduced in new contexts and advising them on regulatory conditions that may apply.

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