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The Effects of Locational Factors on the Performance of Innovation Networks in the German Energy Sector

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Abstract: Locational factors, like the quantity and quality of skilled labour, demanding customers, competitors, supporting industries, and research institutions, are assumed to have an influence on the competitiveness of a region and the performance of the regional actors. However, few studies focus on this topic from an innovation network perspective in the energy sector. Our study tries to close this gap: a sample of 128 German innovation networks of companies and research institutes in the energy sector is used to analyse the effects of locational factors on the performance (effectiveness) of innovation projects. Based on the distinctions in Porter's Diamond Model, we find that two locational factors—the quality and quantity of the demand conditions and skilled labour—have positive effects. In contrast to the widespread assumption in the literature we could not find evidence for positive impacts on the quality and quantity of the competitive environment. In fact, the effect on performance was negative.

Keywords: spatial perspective; region; locational factors; diamond model; collaborative innovation projects; innovation projects in the energy sector

1. Introduction

Since the early 1990s regional networks of actors and their effects on regional development have become major topics in economic research and practice [1–3]. Concepts, such as regional innovation systems [4,5] or sector-specific clusters [6], have emerged that describe the necessary industry-specific requirements in a region. These may include comprehensive production systems, demanding customers, adequate infrastructures, governmental support, research institutes or universities [7,8]. In addition, both concepts emphasize the systematic interaction between different actors calling for physical proximity [5,9]. Moreover, the concept of open innovation (OI) has been recently introduced to relate the innovation capability of firms to inter-organizational cooperation and interaction. Here, the participation in innovation networks and alliances [10] constitutes one of the three OI core processes [11,12]. Even today, when digital communication allows OI cooperation and interaction across longer distances [13,14], regions are still assumed to be important "starting and transit points" for successful innovations [15] (p. II).

Our interest here is to link the performance of collaborative innovation projects to regional factors, e.g., locational factors. The question is whether locational factors related to the regional starting point of the innovation (are perceived to) have an impact on the success of these projects. Cluster theories—in particular Porter's Diamond Model—have emphasized the strong relationship between local/regional resources, but also local/regional competition, and productivity as well as the innovative ability of firms whilst largely taking a national perspective [16]. Local/regional resources consist for example of “venture capital, skilled labour, specialized suppliers, knowledge-intensive services and demanding customers” [17] (p. 232). We argue that local/regional resources and competition also have a stimulating effect on the performance of collaborative innovation projects in particular when project members are all located within the same region. A considerable amount of literature has already emphasized the potential relationship between inter-firm networking and the conditions of firms’ local operating environment in shaping their innovative activity. Empirical analyses have been largely carried out as case studies at the regional level [18]. At the firm and collaboration level empirical evidence is rather limited with regard to both the investigation of localized inter-organizational linkages and the importance of local context conditions (in the following: locational factors) [19]. In addition, the few empirical studies have focused only on a limited number of selected locational factors and presented inconsistent results. For example, Baptista and Swann explored the innovation capacity of manufacturing firms in the UK and found a greater probability of innovating if the market share is high and the competition is more intensive [20]. On the other hand, the study by Geroski showed for the UK that rivalry, e.g., a large number of (small) firms in the same region, is less important than technological opportunity when it comes to innovation activities [21]. Overall, a relative importance ranking of locational factors is missing with regard to the collaboration level. This paper aims to close this gap relying on the perspectives of network managers and focussing with the energy sector on a specific industry.

The reason for concentrating on the energy sector is that geographical aspects have also started to receive attention within the sustainability transitions literature [22]. Research has investigated innovation dynamics with regard to a sustainable transition into an innovation system based on an economy, sector, or region. Aspects, such as “public policies, institutional settings, inter-organisational networking, learning processes and knowledge infrastructures, and entrepreneurial capabilities” [22] (p. 437) are analysed. A multi-level perspective is used, e.g., at local/regional (niche), national (regime) and international levels (landscape) [23]. In particular, the interplay between local nodes/clusters (regions) and global networks is of interest. Regions can be considered as niches, e.g., “protected spaces (. . .) in which radical innovations can develop without being subject to the selection pressure of the prevailing regime” [23] (p. 957). Their assets in terms of resources, actors, institutions and technology are hypothesized to “make substantial contributions to transition processes” of technological innovation systems [24] (p. 976). Regions are considered to offer benefits such as “place-identity (reflected in ‘public sentiments’), local knowledge and relational resources” [22] (p. 444). With regard to sustainability transitions, the focus is on specific technologies enabling sustainable innovations, e.g., renewable energy technologies. Policies aim to stimulate innovation by supporting the transfer of innovative ideas and knowledge from universities to firms, e.g., with programmes funding collaborative innovation projects [25].

One example of politically-induced systemic changes and innovations is the German energy sector. Worldwide, the energy sector is facing a huge challenge, since the increasing demand for energy is connected with a rapid growth in the level of greenhouse gas emissions [26]. In addition, the safety of nuclear power and, consequently, its future has long been discussed, in particular after accidents such as the one in Fukushima in 2011 [27]. Together with the limitation of fossil fuels’ reserves and their large-scale use causing environmental problems, the need for a rapid expansion in renewable energies is further intensified [28]. Germany has become one of the world’s leaders in green energy aiming with policies such as the *Energiewende* (energy transition) “to create a leading position for German industry in renewable energy technologies, boost innovative capabilities and create employment opportunities in future growth markets” [29] (p. 522). By 2022 nuclear power is scheduled to be phased out and by 2050 efforts are being made to reach a 60% share of renewable energy in total energy [30]. National laws have been established, e.g., the Renewable Energy Source Act [31] as well as various programmes and support for research and development (R&D) activities, such as funding of demonstration projects (e.g., ‘Smart energy showcases—Digital agenda for the energy transition’ (Sinteg)) and innovation alliances (e.g., Innovation Alliance Photovoltaics). In addition to a national top-down process to fundamentally change the whole energy system, there is also a bottom-up process driven by the German federal states (Laender) [32]. The German Laender pursue their own expansion strategies with regard to renewable energies [33] and are, in particular, responsible for their implementation on site. This implies that the initiation, promotion and implementation of innovation projects on a local/regional level demands local associated know-how and a local innovative environment. The goal of this paper is to explore Porter-style locational factors (cluster conditions) [34] with regard to their relative importance for collaborative innovation project performance in a politically-induced system transformation (the German energy sector) with a large-scale empirical sample. Several locational factors based on Porter's Diamond Model [34] were operationalized with item scales and evaluated by 128 network managers. The starting point was a population of 608 collaborative energy innovation projects which had being collected from websites of funding programmes and research institutes. These projects were, to a substantial extent, politically induced. In the following the literature relating to locational factors is discussed with a focus on collaborative environmental innovations and hypotheses are derived. Then the empirical database is described followed by the empirical results and a discussion. The last section highlights research implications and presents an outlook for future research.

2. Theoretical Background and Research Hypotheses

2.1. Collaborative Energy Innovation Projects within the Regional Concept

Due to increasing global competition, customer demands, and rapid technology change, firms increasingly rely on collaborations with customers, suppliers, and competitors for the acquisition of external knowledge and the development of new products [35]. Thus, with regard to the transformation of the energy sector the literature emphasizes the importance of networks and collaborations for the development and diffusion of innovations [36]. They are part of a technological innovation system within "a specific economic/industrial area under a particular institutional infrastructure" [37] (p. 93). Technological innovation systems, themselves, "are constituted from networks of artefacts, actors, and institutions" [22] (p. 436). A technological innovation system serves to provide knowledge and other resources, positive external economics, guidance, and market formation [36]. The literature has emphasized the importance of "the characteristics of a firm's regional environment" [19] (p. 757) for innovative performance and empirically confirmed agglomeration effects concentrating innovative activities within a region. In addition, cluster and network theory, and other literature taking the geography of innovation into account, consider the proximity of collaborative partners as a driving force for innovation [19,38,39]. In particular the informal sharing of information resulting from face-to-face communication is considered "vital for new product development" as it supports the generation of new ideas [35] (p. 44).

In his Diamond Model (see Figure 1) Porter emphasized the special importance of geographically-related inter-linkages between economic actors gaining competitive advantage [34,40,41]. The model consists of four elements—'factor conditions', 'firm strategies and inter-sectoral rivalry', 'related and supporting sectors', and 'demand conditions'. Each element is influenced by the two exogenous factors of 'government policy' and 'chance'. According to Porter [16] (p. 78) a cluster is described as a "geographic concentration of interconnected companies and institutions in a particular field". Porter argues that competitive industries are preferably embedded in a specialized cluster with vertical (suppliers of specialized inputs) or horizontal relationships (demanding customers or service providers), as well as research institutions, see also [42]. Firms located within a cluster benefit from access to local government economic policies, natural resources, the local market, highly-skilled labour, and specialized know-how [39]. In addition, knowledge exchange is supported by informal mechanisms based on local collaborative behaviour [19,35].

While the role of universities has been extensively discussed in the literature, fostering technological innovations [35,43,44], other locational factors, such as highly-skilled labour [45,46], a competitive environment [20], demanding customers [45], and economic resources [47,48], have been identified as well, but rarely studied, with a few exceptions [49,50]. Relying on Porters' Diamond Model as a starting point for the conceptual framework of this paper, the selected locational factors of the four elements will be discussed below with regard to their impact on the performance of collaborative energy innovation projects and hypotheses will be developed.

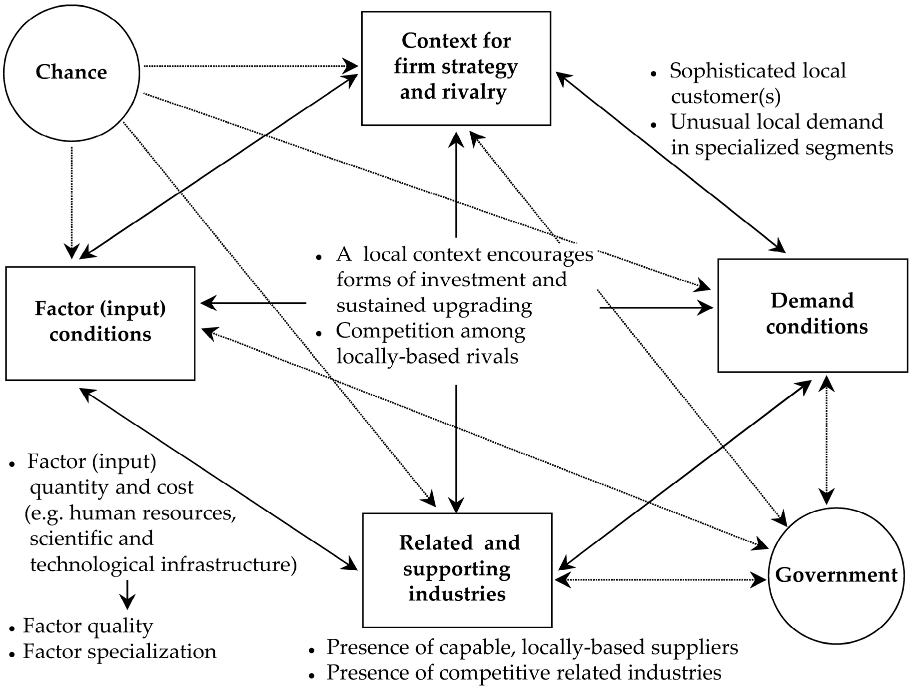

Figure 1. Porter's Diamond Model basing on [40,41].

2.2. *Locational Factors Fostering Collaborative Energy Innovation Projects*

2.2.1. Skilled Labour

Firms located close to a source of knowledge benefit from a better performance of innovation projects due to knowledge spillovers [43,51]. Many innovation studies emphasize the importance of universities and research laboratories as suppliers of specific know-how for generating technological innovations [45,52,53]. In addition, universities are also a source of human capital in terms of higher skilled labour [54,55]. As far back as 1890, Alfred Marshall suggested within his concept of industrial districts that a specialised labour pool is an important driving force for industrial growth [56,57]. Innovation research has also highlighted the importance of highly skilled (academic) labour especially in scientific and technical fields [58]. This is also true when it comes to the development of peripheral areas [59]. Overall, Malecki and Bradbury emphasize that "the location decision for R&D facilities is dominated by the (. . .) need for (. . .) technical and professional workers" [60] (p. 124). Within a cluster firms have the potential to get faster access to competent staff who have left another local firm and to gain new knowledge [61,62]. Information flow and innovation is further accelerated by interpersonal relationships between scientists and highly skilled labour transfer within the region, but also beyond [62]. Success factor analysis has found strong effects of human resources, in particular in high-tech markets, with regard to new product development success, however Evanschitzky et al. [63] (p. 10) come to the conclusion that this factor has been subject to little research "emphasizing the need for further assessment".

Since many renewable energy technologies are still in an early diffusion stage being "available in an early form after several decades of experimentation" [64] (p. 256), competence in technology and innovation is of special importance. Overall, we suggest that local skilled labour is an important locational factor with regard to the performance of collaborative energy innovation projects:

H1: (The quantity and quality of) Skilled labour has a positive effect on the performance of collaborative energy innovation projects.

2.2.2. Demand Conditions

According to Porter's 'theory' of the competitive advantage of nations [16,34], a cluster consists of the knowledge and expertise of cluster actors which are considered to be the driving forces of competitive advantage. In this regard demand conditions as one of the determinants of national innovation capacity stimulate firms to innovate [65]. Specifically, Porter [40] (p. 89) suggests that firms benefit from demanding local customers because they are pushing the firms "to meet high standards in terms of product quality, features, and service". However, individual demand is often deeply hidden and difficult to capture. Hence, to obtain easier access to demand, knowledge firms need to operate in geographical proximity to the customers [55,66].

Justman found, for the U.S., that local demand strongly affects industry location, in particular with regard to high-technology industries [67]. In general, marketplace characteristics, such as 'market potential', e.g., growth in customer demand, have been identified as important new product development success factors [63]. Also at the firm level, Bönte empirically confirmed Porter's assumption that demanding customers in geographical proximity positively influence a firm's innovative performance for the German aeronautic cluster in Hamburg [44]. Fabrizio and Thomas showed with regard to the global pharmaceutical industry that even in a global market, firms are still innovating for the needs of the national innovation system in which they are embedded [65]. We propose that local demand also plays an important role for collaborative energy innovation projects and propose the following hypothesis:

H2: (The quantity and quality of) Demand conditions have a positive effect on the performance of collaborative energy innovation projects.

2.2.3. Competitive Environment

According to Porters' Diamond Model the key factor 'Context for firm strategy, structure and rivalry' includes domestic rivalry [34]. As suggested by the literature of regional innovation systems and cluster theory, high competition in firms' environment has empirically been confirmed to be important to firms' innovation behaviour in general, e.g., for small firms in Korea [68]. Strong rivalry nearby exerts constant pressure on firms to innovate and to improve quality and (production) efficiency, but has a negative effect on local profits [16]. With regard to new product development success, market characteristics such as 'likelihood of competitive response' and 'competitive response intensity' have displayed negative effects [63]. However, according to Porter [40] (p. 137), local rivalry can positively affect "home demand through product and marketing innovation". Furthermore, firms have the opportunity to become more competitive and thus to enhance their reputation by directly observing their competitors [42]. For Taiwanese firms in the information and communication technology industry, Huang has shown that a highly competitive environment enhances a firm's innovation performance [69].

With regard to the development of the German energy sector rapid and unpredictable changes have occurred. The introduction of so-called 'Renewable Energy Feed-in Tariff' systems that reward the generation of renewable energy by the government has increased competition and in consequence offered "opportunities for small market players against monopolistic practices" [70] (p. 685). Competitive firms need to be able to develop technologies (core technology capability, see, e.g., [69]) and to quickly adopt new technologies (absorptive capacity), e.g., to become more resource-efficient and to increase profitability [71]. These capacities enable firms and collaborations to act innovatively in a highly competitive environment. Therefore, we derive the following hypothesis:

H3: (The quantity and quality of the) Competitive environment has a positive effect on the performance of collaborative energy innovation projects.

2.2.4. Related and Supporting Industries

Related and supporting industries directly or indirectly affect the focal sector in a cluster [34]. Porter argues that existing successful suppliers, service firms or venture capital investors provide opportunities for communication and technological exchange as well as creating demand for complementary products. Even in Germany venture capitalists tend to invest in firms which are located close-by due to information and monitoring costs increasing with distance and unfamiliarity with "regional particularities, markets or service providers" [72] (p. 2347). One main reason for choosing a location near to suppliers is to achieve efficient economies of scale [42,62]. In addition, complementarities between firms and suppliers can support new product development in terms of idea generation or the use of new methods and/or technologies [50]. The geographical proximity facilitates faster transportation and information flow, as well as closer communication, in particular, in knowledge-intensive industries [34,62]. Overall, related and supporting sectors enable energy firms to "share activities intersectorally in the value chain, e.g., technology development, suppliers, distribution channels and marketing" [73] (p. 194). At the firm level empirical research found mixed results. The study of Boasson and MacPherson establish no significant effect of the presence of related and supporting industries on the innovative and financial performance of publicly traded companies in the U.S. pharmaceutical industry [74]. However, in the study by Lejpras et al. analysing a sample of 2345 firms predominantly from the manufacturing sector and located in East Germany, this effect was significantly positive with regard to both performance indicators [50].

With regard to the German energy sector Dögl et al. [73] (p. 206) come to the conclusion that related and supporting industries, which are, in particular, high-tech industries, such as nanotechnology or process engineering, are "well developed". Overall, we propose that related and supporting industries are important for collaborative energy innovation projects:

H4: (The quantity and quality of) Related and supporting industries have a positive effect on the performance of collaborative energy innovation projects.

2.2.5. Political Support (Government)

Government can promote national competitiveness with various kinds of policies and regulatory measures, e.g., financial incentive programmes, subsidies, tax credits or market regulation frameworks [34,75]. Literature has emphasized innovation policy as a driver of technological change [76]. In addition to technology push and demand pull factors to explain innovation activities [77], governmental policy is considered to be necessary for renewable energy innovation projects [78]. Renewable energy technologies suffer from uncertain financial returns for the R&D investment and the perception of not being competitive with conventional energy technologies in terms of costs [78,79]. Dögl et al. come to the conclusion that "without public support there would be no market for renewable energy technologies" [73] (p. 201). In addition, because of negative external effects when solving environmental problems, e.g., waste reduction, there is no incentive for firms to engage in the creation of innovations [80]. Thus, policy has become a key driver of renewable energy technologies employing incentive-based instruments and regulatory approaches [64]. Porter and Linde [81] (p. 98) have put forward their controversial hypothesis "that properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them". However, empirical studies have shown inconsistent results. This holds for studies investigating (stricter) regulations and the creation and adoption of environmental innovations by firms [82,83], but also with regard to R&D subsidies [84]. With regard to government support (e.g., from business development corporations, local authorities, job centres and the state government), Lejprcas et al. could only confirm a positive effect on innovative and financial performance for less-innovative firms [50].

However, the transformation of the energy sector is a long term project which "requires far reaching changes, many of which date back several decades and involve political and policy support in various forms" [64] (p. 257). Thus, we propose that political support and in particular R&D subsidies to financially support the development process are important for collaborative energy innovation projects that are still at an early development stage:

H5: (The quantity and quality of) Political support has a positive effect on the performance of collaborative energy innovation projects.

3. Data and Measurement

3.1. Database and Sample Characteristics

We started by collecting innovative collaborations working together on a joint research and development project dealing with renewable, but also conventional, energy innovation. The focus was not on pure fundamental research. The projects were expected to have an explicit commercialization agenda. Different sources were used as starting points, in particular websites of different German Federal and Federal state ministries providing information on funding programmes, websites of German research institutes (e.g., Fraunhofer, Helmholtz) containing project lists, websites of the German Renewable Energy Research Association (FVEE—ForschungsVerbund Erneuerbare Energien), industry associations (German Solar Association and the European counterpart), or energy agencies (Agentur für erneuerbare Energien) [77]. In addition, a database that had been used in two previous studies [85,86] was searched for suitable innovation projects. The search resulted in 608 German collaborative energy innovation projects. The database contained information about the project and contact information with regard to the project manager. The projects were assigned to an energy field and an energy source by one of the authors. Overall, it should reasonably be expected that a substantial part of the projects was publicly (co-)funded. A preliminary analysis of the population sample showed that 77% of the network managers and their organizations were located (10 km and less) very close to a university or research institute. Another 21% were up to 40 km away [87].

After two experts had pre-tested the questionnaire, a written and online version were used for data collection between April and November 2012. The network manager of the innovation project was the primary and only contact throughout data collection. The initial contact was made via mail and, subsequently, in two follow-up rounds via phone and email. The response rate was high at 21% and 128 returned questionnaires. The data was tested for non-response bias taking the sample population of all collaborative energy innovation projects into account, and response bias, e.g., comparing respondents providing a written or online survey, with regard to several characteristics [88]. Only few significant differences at the 0.10 level were found with regard to the distribution of the energy conversion sources in the sample and the sample population [77].

The focus of the innovation projects is on energy conversion being implemented in system and process innovations. With regard to the energy source most of the projects concentrated on solar energy and bioenergy. Energy storage projects frequently made use of thermal or chemical approaches. The collaboration projects were rather small with on average about seven partners (mean value: 6.77) taking part. The projects had an average duration of 3.5 years. Most innovations had not been brought to the market, but were still under development (see Table 1). Research institutes and universities were involved in 76.4% of the innovation projects followed by partners dealing with energy technology (50.4%), production technology (48.0%), services (31.5%) and materials technology (26.0%). Regarding their geographic location most partners were nationally (63.8%) and, to a lesser extent, regionally distributed (17.3%). The percentage of local and international partners is similarly low at 8.7% and 10.2%. To support fast classification distances were given in kilometres, e.g., 10 km (local), up to 50 km (regional), 51 km and more (national).

Table 1. Descriptive characteristics of the sample (in %) (see also [77,89]).

Type of Innovation [1]			
System	Process	Product	Service
34.7 (n =46)	29.0 (n =38)	25.8 (n =32)	10.5 (n =14)
Energy Field [2]			
Energy conversion	Energy storage	Energy distribution	Others
82.8 (n = 106)	33.6 (n = 43)	17.2 (n = 22)	18.0 (n = 23)
Energy Conversion [2]			
Wind energy	Bioenergy	Solar energy	Fuel cell
13.3 (n = 17)	22.7 (n = 29)	30.5 (n = 39)	5.5 (n = 7)
Geothermal energy	Hydro power	Conventional power plant	
10.2 (n = 13)	4.7 (n = 6)	14.8 (n = 19)	
Energy Storage [2]			
Thermal	Chemical	Electric	Mechanic
46.5 (n = 23)	39.5 (n = 17)	14.0 (n = 6)	9.3 (n = 4)
Stage of the Innovation Project *			
Building a business case	Development stage	Testing & validating	Launch
17.3 (n = 22)	36.2 (n = 46)	28.3 (n = 36)	18.1 (n = 23)

Notes: [1] Due to a few multiple answers the numbers were normalized to 100%; [2] Multiple answers are possible; * one missing answer.

3.2. Operationalization and Measure Validation

The design of the questionnaire relied on the literature and suggestions by experts [77,89]. We measured how network managers judged locational factors and the collaborative performance using a seven-point Likert scale from 1 = 'strongly disagree' to 7 = 'strongly agree'. The questionnaire items for the independent and dependent measure(s) used in the analysis are listed in the Appendix A.

3.2.1. Locational Factors

The locational factors comprise the factors of the Diamond Model: 'demand conditions', 'competitive environment', 'skilled labour', 'related and supporting industries', and 'political support'. The item scales for each of the locational factors had to be newly developed, relying on conceptual considerations and variables used in assessments with regard to the key factors and the exogenous variable 'government' from the model developed by Porter [50,90,91]. We assumed that the variables used in the studies that in part investigated other countries and made no restrictions with regard to the industry can be transferred to the context of the energy sector. Concerning customer characteristics, the focus is on demanding customers who value novel technologies (trend leaders, open to new products and processes) and have the necessary financial resources [91]. The characteristics of the competitive environment include the number and the size of competitors [50] and their capacity in terms of innovativeness and performance [90]. For the local supply of skilled labour, the availability of highly qualified and specialized personnel (e.g., R&D personnel, university graduates, and technicians) as well as a basic research infrastructure were selected [91]. With regard to the factor 'related and supporting industries', the availability and density of service providers and suppliers [90,91], but also of other firms in terms of the technological basis and innovativeness were considered to be relevant for the energy sector. Finally, the 'political support' factor consisted of financial support at different levels, as well as support from local politics and local government promotion, e.g., by regional business development [50].

3.2.2. Performance

In a similar way the outcome variable, which we refer to as perceived collaborative project performance, was measured as a self-reported evaluation by the network managers. The best way to measure the success of a (product) innovation is to rely on objective measures such as return on assets or growth in sales [92] or number of innovations introduced to the market in a specific time span (process innovation) [93]. In that case an ex-post perspective is used. However, the energy innovation projects being studied were still at the development stage. Therefore, objective measures are absent. Since there is a correlation between objective and subjective measures [92], we rely here on a subjective measurement scale. This measure was previously developed and used in project and teamwork research investigating innovation projects, e.g., in the information technology [94,95]. Perceived project performance is related to the outcome of a project (effectiveness) in terms of (technical) quality (e.g., competitive advantage) and attainment of desired qualities and specifications (pride in achievement). In addition, aspects of market performance are included, such as gained reputation [94,95]. Items dealing with customer satisfaction and financial performance measures (profit and revenue goals) were not used due to the (early) stage of the development process. Since [96] found no measurement differences with regard to (perceived) innovativeness we expect the items to measure consistently across the phases of the innovation process.

3.2.3. Assessing the Measures

With regard to the quality of the item scales (reliability, validity, uni-dimensionality) all factors were tested with regard to the threshold of several generally-accepted criteria stated in the literature, e.g., Cronbach's $\alpha \geq 0.7$ [97], average variance extracted (AVE) ≥ 0.5 [98], and composite reliability ≥ 0.6 [99]. The last two values were calculated relying on an unweighted least-squares estimate (ULS) since the sample size was small [100]. Due to their low item reliability one item of the 'demand conditions' factor and two items of the 'political support' factor had to be dropped. Overall, the measures used in this analysis showed satisfactory results (see Table 2). With regard to the 'political support' factor, the three items focused on regional aspects and formed a 'regional subsides' factor consisting of support from regional promotion of commerce, local policies and R&D funding programmes by the German federal states. The other two single items on national and EU R&D subsidies were retained for the analysis.

Table 2. Summary statistics of quality criteria.

Factor	Number of Items (Initial)	Mean (std.)	Cronbach's α	Explained Variance	AVE	Composite Reliability
Skilled labour	5	5.06 (1.33)	0.897	70.98%	0.640	0.898
Demand conditions	4 (5)	4.35 (1.33)	0.868	65.99%	0.548	0.828
Competitive environment	4	3.06 (1.58)	0.911	79.32%	0.735	0.916
Related and supporting industries	4	4.41 (1.56)	0.926	81.87%	0.763	0.928
Political support (R&D subsidies)	3 (5)	3.48 (1.76)	0.851	77.34%	0.660	0.853
Performance (effectiveness)	5	5.69 (0.96)	0.882	68.29%	0.602	0.883

Notes: scale: 1 = 'strongly disagree' to 7 = 'strongly agree'.

4. Results and Discussion

4.1. Results

We addressed the question of whether locational factors have a positive influence on the collaborative project performance of energy innovation projects by regressing locational factors on project effectiveness. The results (see Table 3) of the VIFs (all values less than 2) and the CN (less than 30) indicated no problems with possible multicollinearity. Skilled labour and demand conditions both showed a significant positive relationship with collaborative performance supporting H1 and H2. Skilled labour even had a higher impact than demand conditions.

(Regional) political support also displayed a positive, but not significant, impact. H5 could, therefore, not be confirmed. In contrast, there was a significantly negative effect of the competitive environment and no effect of related and supporting industries which means no support for H3 and H4.

Table 3. Results of the regression analysis.

Locational Factor	**Project Performance (Effectiveness)**	
	Regression Coefficients	**VIF**
Skilled labour	0.283 **	1.346
Demand conditions	0.193 *	1.306
Competitive environment	−0.306 **	1.262
Related and supporting sectors	−0.143	1.436
Regional political support	0.119	1.142
Condition index		13.340
R^2 (adjusted R^2)	0.176 (0.142)	
F	5.195 ***	

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.050$.

In addition, the collaborative energy innovation projects were divided into two groups according to the geographical distribution of the partners and investigated with respect to the locational factors (see Table 4). A smaller group A consisted of collaborative energy innovation projects formed by partners out of the region (26%). A much larger group B (74%) included innovation projects with partners distributed nationally, and even internationally.

Table 4. Comparison of geographical distribution of partners in terms of the locational factors.

Factor	**Group A Local/Regional ($n = 33$)**	**Group B National/International ($n = 94$)**	***T*-Value**
	Mean (Stand. Deviation)		
Skilled labour	5.34 (1.16)	4.95 (1.39)	1.440
Demand conditions	4.52 (0.99)	4.28 (1.44)	1.038
Competitive environment	3.58 (1.19)	2.85 (1.66)	2.724 *
Related and supporting industries	4.76 (1.56)	4.29 (1.56)	1.487
Regional R&D subsidies	4.12 (1.41)	3.29 (1.82)	2.705 *
National R&D subsidies	4.94 (1.58)	5.17 (2.00)	−0.599
EU R&D subsidies	3.85 (1.73)	3.56 (2.07)	0.770

Notes: * $p < 0.05$; scale: 1 = 'strongly disagree' to 7 = 'strongly agree'.

In general, network managers in group A tended to assess the locational factors with higher values than network managers in group B with the exception of national R&D subsidies. The competitive environment and also regional R&D subsidies are evaluated significantly higher by network managers of networks consisting exclusively of local/regional partners. A reason for these results might be that network managers of 'regional' networks have closer links within their region, e.g., due to the exchange with their local/regional partners.

4.2. Discussion

These findings make a contribution to the discussion on locational factors and their influence on the performance of collaborative energy innovation projects. Porter's Diamond Model is used to develop hypotheses and the relative importance of each of the five factors is tested. The empirical investigation collected the subjective perceptions of the network managers with regard to the locational factors, but also with regard to project performance. The regression analysis provided the following results: First, skilled labour and demand conditions have significant positive effects on project performance. Skilled labour was perceived to be highly relevant throughout the development process, e.g., with regard to the development phase no significant differences were found. In all phases of the development process highly skilled staff with profound and special technological competences were regarded as particularly necessary for collaborative energy innovation projects. As we have previously discussed in the theoretical section, skilled labour substantially contributes to achieving quality goals and to fostering innovations. However, since the innovation process is geographically distributed, the perception of the network manager might be biased with regard to their location. The different locations of the network partners make it difficult to match the subjective perceptions of the network managers with regionally-available 'hard' data, e.g., the unemployment statistics or distance from university locations. In addition, network managers consider demand conditions to be a success factor. The German energy sector is perceived to have demanding customers (mean value: 4.70) that are open towards new products and processes (mean value: 4.52). Even if not significant, demand conditions are regarded as more relevant in the planning and launch phase. This finding is consistent with the study of Rehfeld et al. showing that customer satisfaction is an important factor during the diffusion phase [101].

Second, the negative significant estimation of the competitive environment on performance does not support Porter's assumption on the firm level that rivalry between firms fosters competitiveness. Wu has discussed several reasons for a competitive environment to have a negative (moderating) effect on collaboration. For example, in high-technology sectors partners in collaborations behave hesitantly and refrain from collaborating because competitors could use knowledge spillovers for their own competitive advantage [102]. Furthermore, a competitive environment can tempt a firm to pursue short-term targets at the expense of a collaborative relationship, in particular, if customers expect a quick response [103,104]. With regard to the energy sector, quick technological realizations of solutions to transform the energy sector into a renewable one are not (yet) required by the customer, but should achieve predetermined political objectives.

Third, even though political support is characteristic for the energy sector in Germany the perception of the network managers results in a small positive, but no significant relationship with project performance. The study of Cuerva et al. investigating 301 Spanish food and beverage firms found similar results with a small negative (non-significant) effect of public funds on environmental innovation [104]. In contrast, the effect was highly significant for conventional innovation. The participants were asked whether they had received public financial funds from the EU, central government, or regional governments. The authors came to the conclusion that subsidies are not effective "among the environmental policy instruments to trigger the green innovation" [104] (p. 110). However, financial resources are relevant, since financial constraints (due to low customer demand) had a significant negative effect on the development of green innovation. Overall, the focus of the decision-makers in companies seems to be more on the profitability of the projects. The study by Hashi and Stojčić explained the significant positive influence of national and EU funded subsidies, but not local/regional subsidies on the innovation output in "stricter criteria" for obtaining national and EU subsidies [105] (p. 360). The divergent effect of local/regional subsidies is suggested to be the result of local policies. Often local policies aim to create beneficial preconditions allowing local-oriented innovation projects to better meet their objectives. For example, Schwerdtner et al. proposed "Regional Open Innovation Roadmapping" (ROIR) to foster the development and implementation of sustainable innovative ideas in a region [3]. The findings of our study showed that network managers of collaborations with partners located in the same region evaluated regional financial, but also non-monetary, support significantly higher than collaborations with partners across regions. The participants in these networks seem to be better integrated into the local networks of policies and value their effect much higher.

5. Conclusions and Implications

The analysis started with an overview of the development of the energy sector taking environmental and political aspects into account [28,31,106]. The literature proposed that national economic and political targets could only be achieved by a collaborative approach on the local level which calls for the stimulation of collaborative innovation networks [107]. To identify the most important locational factors special characteristics of Porter's cluster concept [16] were taken into account. Regarding collaborative energy innovation projects, the locational factors 'demand conditions', 'skilled labour', 'competitive environment', 'political support', and 'related and supporting sectors' were discussed [20,42,44,46,80]. Based on Porter's Diamond Model [34] we developed measurement scales for examining the influences of locational factors on project performance for energy innovations. The regression analysis showed that skilled labour, and to a lower degree, demand conditions, have a positive effect on collaborative performance. Contrary to Porter's perception, but consistent with success factor analysis, a competitive environment has a negative effect on collaborative performance. In addition, no support was found for H3, H4, and H5.

However, several limitations must also be considered. Regarding the sample size, 128 collaborative energy innovation projects represent only a proportion of all projects even if we tried to identify all relevant energy collaborative innovation projects in Germany. The composition of the basic population is confronted with the problem of a selection bias. Only those energy innovation projects that had reached a business case status and were announced on websites were included in the basic population of 608 projects. In addition, most of these projects received public funding, overall demonstrating some degree of success. In contrast, projects failing at a very early stage were not included because it would be a challenging task to collate them. Success, as well as locational factors, were measured relying on self-reported scales and the perception of one informant, the network manager. Several biases, e.g., retrospective bias and common source bias have to be considered [108]. Network managers might tend to let their network appear in the best possible light. To avoid common source bias several perspectives of a collaborative innovation project should be collected. Due to the data facing several biases, the ability to generalize the findings is rather limited. In addition, only about 17% of the project performance is explained by the locational factors. Therefore, the analysis should include additional important success factors concerning typical categories, such as product, strategy, development process, marketplace, and the organization [63], and these should be included [86,89]. The geographical distribution of the partners should be based on more objective and detailed information to give a complete picture on the influence of the same or different local environment(s). However, our study does increase the understanding of the relative importance of spatial context conditions for energy innovation projects in Germany on the perception of network managers. Previous research relying on the database had shown no response bias when comparing the results of the quantitative analysis with a case study sample [86,109]. The non-significant results in particular with regard to political support should be addressed and investigated in more detail by taking more support instruments into account in future research.

Appendix A

Appendix A.1. Item List (Translated from German)

Appendix A.1.1. Skilled Labour

For our product innovation the region has...

(1) ... enough personnel for research and development available.
(2) ... enough university and applied science university graduates available.
(3) ... enough other professionals, such as technicians, available.
(4) ... enough universities with relevant fields of study available.

(5) ... enough research institutes with relevant research priorities available.

Appendix A.1.2. Demand Conditions

Customers in the region...

(1) ... are there in sufficient numbers (dropped).
(2) ... are there with sufficient financial strength.
(3) ... are very demanding.
(4) ... are very open towards new products and processes.
(5) ... are often trend leaders (lead users, innovators).

Appendix A.1.3. Competitive Environment

Competitors in the region...

(1) ... are there in large numbers.
(2) ... are similarly high-performing.
(3) ... are similarly innovative.
(4) ... are similar in size.

Appendix A.1.4. Related and Supporting Industries

For our product innovation the region has...

(1) ... many service providers (maintenance, construction, IT services, etc.) available.
(2) ... many suppliers available.
(3) ... many companies that have access to similar technologies available.
(4) ... many companies that are similarly innovative and technology oriented available.

Appendix A.1.5. Political Support (R&D Subsidies)

In the region there is sufficient support by . . .

(1) ... regional economic promotion (regional R&D subsidies).
(2) ... local politics (regional R&D subsidies).
(3) ... suitable R&D funding programmes of the German federal states (regional R&D subsidies).
(4) ... suitable R&D funding programmes of the German government (national R&D subsidies).
(5) ... suitable R&D funding programmes of the European Union (EU R&D subsidies).

Appendix A.1.6. Collaborative Project Performance

The innovation . . .

(1) ... has greatly increased the reputation in the industry for all partners (effectiveness).
(2) ... provides all partners with a competitive advantage (effectiveness).
(3) ... is of excellent (technical) quality (effectiveness).
(4) ... fills all partners with pride concerning the results so far (effectiveness).
(5) ... meets pre-established goals (effectiveness).

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