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# Innovation networks and green restructuring: Which path development can EU Framework Programmes stimulate in Norway?

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**ABSTRACT.**

This paper examines the engagement of different regions in Norway in the EU's environmental programmes. The aim is to explore the programmes' potential for supporting green restructuring through branching and new path creation. The paper assesses which regions participate in the programmes, which international networks they build, and which organisations participate in different regions. It compares three regions with different restructuring needs and research capacity – Rogaland, Hordaland and Sør-Trøndelag. Overall, Norwegian organisations participate relatively frequently in the programmes, but private firms play a marginal role. Their partners are mainly in core EU regions. Regional participation in the programmes is a function of research capacity as well as oil dependence. However, in research-oriented regions, research establishments tend to dominate participation, creating potential for restructuring mainly through path creation. In oil-dependent regions, private firms account for a higher share of participants, enhancing the potential for branching. As the former regions participate more, the programme can mainly stimulate path creation.

## 1. Introduction

Addressing environmental problems is an important motivation for innovation policies. Among other programmes, the European Union's (EU) Horizon 2020 funds international research collaboration to address environmental issues. An expert committee appointed by the Norwegian government al internatio so recommends directing R&D towards addressing environmental issues and promoting nal research collaboration (Hedegaard & Kreutzer 2016). The aim is to develop green competitiveness and thereby support the transition to a more sustainable economy. In this context, it is of interest to examine the ability of R&D funding in this area to mobilise different types of actors and regions into international research collaboration networks.

Economic restructuring requires new path development, which can take place through branching or new path creation. These (normally regional) processes require different types of policy stimulus. Branching, which is moving into new but related industries (Boschma 2017; Isaksen et.al 2018; Grillitsch et al 2018), requires mobilising existing industries and bringing in complementary knowledge through international collaboration (Trippl et al. 2017). These processes are more important in industrial regions with a need for restructuring. Path creation implies a central role for research establishments which can link up to leading international institutions and foster breakthrough research (Isaksen 2015). These processes usually take place in regions with strong research capacity.

This paper analyses the mobilisation of Norwegian regions and organisations in the EU's environmental programmes, asking whether it reflects potential for branching or new path creation. We focus on three related questions: Which regions participate in the programmes? Which international networks do these regions establish? Are there differences in which types of organisations participate? We examine participation in the Sixth and Seventh Framework Programmes (FP6 and FP7) and Horizon 2020 (H2020). In particular, we compare three structurally similar counties with different needs for restructuring and research capacity – Rogaland, Hordaland and Sør-Trøndelag. Following the research questions stated above, we investigate whether the participation in environmental programmes reflect the potential for branching and new path creation towards a greener economy, and whether there are any differences across regions in the impact of the programme.

## 2. Green economic restructuring

### *2.1. Transition towards a greener economy*

Policy-makers increasingly emphasize the need for innovation to solve grand societal challenges, extending the motivation for innovation policy beyond economic competitiveness (Kuhlmann & Rip 2014). Societies across the world need to transition towards a more sustainable economy to reduce global warming and other negative environmental effects of production and consumption. This requires innovation, e.g. to improve technologies for renewable energy production, make transportation and building solutions more efficient, or develop technologies for carbon capture and storage (European Commission 2011). Accordingly, governments are redirecting R&D funding towards research and innovation in these areas (Johnstone et al. 2010; Wüstenhagen & Menichetti 2012; Mazzucato 2015). Transition also requires more sustainable technologies to replace existing technologies, making user and industry involvement in the R&D projects important.

Transition is not just a function of new technology, but requires transformative changes in production and consumption – in short a change in the socio-technical system (Geels & Schot 2007). Literature on sustainability transitions stresses the importance of policy measures that could lead to environmental technological change (Schmidt et al. 2012). Environmental policy strategy is a combination of policy objectives and plans targeting social and economic issues (e.g. economic growth, competitiveness and new jobs), in addition to environmental objectives.

The participation of different types of organizations in joint R&D projects is a relevant instrument for developing niche technologies within a broader systemic approach to economic restructuring (Rogge & Reichardt 2016). Niches refer to "alternative technologies, practices, structures and actor-constellations deviating from dominant socio-technical systems" (Kivimaa & Virkamäki 2014, 30). Potential technological transitions at the micro-level (niches) must subsequently be embedded in a broader socio-technical regime (Markard & Truffer 2008; European Commission 2015). In the transition, a first phase - generally characterized by new firm entry, knowledge diffused through innovation networks and uncertainty at the institutional level - is followed by a second phase in which the ongoing transition affects the activity of incumbent firms, new business models emerge and policymakers outline clearer visions on new development paths (Markard 2018).

### *2.2. The geography of green restructuring*

Although economic geographers have long been interested in innovation, its role in solving environmental challenges is relatively unexplored in the field (Truffer 2008; Aoyama 2011). Until recently, the sustainability literature largely ignored its spatial dimensions (Hansen & Coenen 2015). Meanwhile, economic geographers have largely not engaged in the discussion on grand challenges (Coenen et al. 2015a). The geography of sustainability transitions literature emerged mainly since 2010, predominantly examining how niches develop in specific places and new technologies emerge. As Essletzbichler (2012) notes, green niches and development paths tend to be geographically localised and often emerge outside the core. Previous research also highlights multi-scalar interactions and non-local relationships (Hodson & Marwin 2010; Essletzbichler 2012; Lawhon & Murphy 2012; Uyarra & Gee 2013), which can break up existing constellations of actors in decision-making networks, allowing for transition. Economic geographers are called to adopt a multi-scalar approach in order to "comprehensively understand in which situations and for which purposes relations at different scales matter" (Hansen & Coenen 2015, 104).

Garud and Karnøe (2003) identify bricolage and breakthrough as two contrasting transition approaches. Rather than aiming for high-tech breakthroughs, the (often more successful) bricolage approach emphasizes scaling up from simple low-tech solutions and building on widely distributed local knowledge from a range of actors. In the transition towards a green economy, it is not sufficient to develop new technologies. Transition requires regional economies to change their production systems by adopting new technologies and developing new products, services and business models (Markard & Truffer 2008; Coenen et al. 2015b). It is a local problem as well as a global one. Each region must develop competitiveness in areas compatible with the green economy in order to secure future well-being. This challenge is greater for regions where the current sources of competitiveness lie in less green industries. They face a profound transition of their economies, requiring concerted efforts by innovators, researchers and investors, as well as an appropriate innovation policy.

However, the lack of attention to geography suggests that innovation policy for sustainability transitions might be as spatially blind as traditional innovation policy (Hansen & Coenen 2015). Green innovation policy programmes remain mainly oriented towards R&D and rely on competition between different networks for access to scarce funding. These characteristics make them potentially more attractive to universities and research organisations than to industry (Roediger-Schluga & Barber 2008; Steen & Hansen 2018). Consequently, funding for green innovation projects might predominantly mobilise regions with stronger initial endowments of research capacity, rather than those facing the largest economic restructuring challenges. If these regions leverage their research capacity to develop transformative innovations that can be implemented across the economy, this can be an effective strategy. However, for transition to succeed, there is a need to disseminate new technologies into regions and industries that need to adopt them.

## 3. How do regions restructure?

### *3.1. Innovation networks, knowledge exchange and new path development*

The need for regional economic restructuring brings sustainability transitions into contact with evolutionary economic geography (EEG), which offers complementary perspectives to those found in transition studies (Essletzbichler, 2012; Boschma et al. 2017). The EEG perspective on restructuring sees regional economic development as path dependent. This may result in regional lock-in, when innovation activities predominantly take place along existing technological paths

(Coenen et al. 2017). This makes it harder to move into new directions, resulting in weak regional competitiveness (often referred to as path exhaustion).

For regions which are locked in to unsustainable technological paths, successful transition requires new path development. Regional branching refers to building on knowledge from existing non-green industries to develop new competitiveness in green industries (Grillitsch et al. 2018). Path creation refers to the establishment of new firms in new sectors. This is often based on commercialisation of research or on external investment (Tödtling & Trippl 2013), and may require appropriate policy interventions (Dawley 2014). The EEG literature emphasizes the role of innovation in restructuring processes, and furthermore the need for knowledge exchange through networks to achieve this (Truffer & Coenen 2012).

Collaboration with other organizations allows firms to benefit from new skills, ideas and resources. Innovation networks provide firms with a broader knowledge base and hence improve their potential for innovation (Powell & Grodal 2005). Economic geographers have focused on the spatial and relational dimensions of collaborative configurations (Giuliani 2007; Calignano 2014; Calignano 2017). Network structures have been examined in-depth with the objective to reveal how the geography of knowledge sources shape innovation (Balland et al. 2013). Innovation networks often have a set of core regions which act as junctions in the knowledge exchange dynamics, although the identity of these regions differ across technologies (Paci & Batteta 2003). It can be difficult to access these networks, as access presupposes the sharing of knowledge. Such knowledge is hard to acquire and mainly exchanged within the networks, creating self-reinforcing dynamics (Autant-Bernard et al. 2013). Preferential attachment (the tendency of new nodes to connect themselves with nodes that are already well connected; Barabàsi & Albert 1999) and path dependence (Martin & Sunley 2006) play a critical role in innovation networks and shape core-periphery dynamics (Sun & Liu 2016).

### *3.2 Geography of knowledge sources and new path development*

While literature in economic geography has traditionally been preoccupied with local knowledge exchange, recent research emphasizes multi-scalar interactions. Actors, networks and institutions operate simultaneously at various geographical scales. The ability to bridge such scales by means of relationships and stable cooperation patterns is essential for firm innovation. Following Binz & Truffer (2011), innovation should be examined as interdependent processes in a multi-scalar perspective. In particular, firms in peripheral regions can potentially benefit from long-distance knowledge flows (Bathelt et al. 2004; Grillitsch & Nilsson 2015;   & Rodríguez-Pose 2011a, 2011b). These connections are not without challenges, as it is more difficult to transfer tacit knowledge across large distances. Geographical proximity is also associated with proximity in other dimensions which are important to knowledge exchange, such as social or institutional proximity (Boschma 2005). Furthermore, long-distance collaboration requires an absorptive capacity which is often lacking, especially in small firms (de Jong & Freel 2010). An important function is therefore held by gatekeepers (e.g. universities or knowledge-intensive firms) which acquire knowledge through international networks and diffuse it to other regional firms (Graf 2010; Giuliani 2011).

International innovation networks may be particularly important when economies and, in particular, highly specialized or peripheral regions (Trippl et al. 2017) try to break away from lock-in situations. They may enable countries and regions to recombine competences (Frenken 2000; Fitjar & Rodríguez-Pose 2013), helping them to avoid lock-in to obsolete technological trajectories. The need for international networks in the Norwegian context in particular is also the conclusion of Narula (2002). He identified lock-in between dominant industries and leading research institutions as a key challenge, resulting in inertia among firms outside the industrial core, and concluded that "relying solely on in-country competences may lead to a sub-optimal strategy" (Narula 2002, 814).

Different regional innovation systems are associated with different potential development paths and related policy and networking requirements. Fostering path modernization (upgrading of existing industries based on new technologies) and branching (diversification into related industries) is important in 'thick and specialized' systems such as the oil-dependent Norwegian regions (Isaksen et al. 2018). A recent study on the transition from offshore oil and gas to wind suggests how diversifying into related industries (branching) is a critical factor in enabling new path development in Norway (Steen & Hansen 2014).

## *4. Innovation networks in EU framework programmes*

### *4.1. Findings of previous studies examining the FPs*

In this context, the EU's FPs represent an important policy initiative. They promote innovation networks involving distant partners at various geographical scales (Calignano 2017). Several studies have examined the innovation networks created in these programmes (Breschi & Cusmano 2004; Autant-Bernard et al. 2007; Must 2010; Wanzenböck et al. 2015). Roediger-Schluga & Barber's (2008) revealed the existence of network hubs, a stable core of connected actors since the early FPs and growing integration among the organizations involved in the various programming cycles. Consortia are often based on past collaboration and existing personal or institutional relationships, reinforcing this pattern. Technological and social proximity, more than geographical proximity, drive the formation of new linkages (Scherngell & Barber 2009; Calignano 2014). Universities and research centres play a central role within the networks. Norwegian research organisations have found it difficult to collaborate with user partners and have struggled to include high-quality industrial partners in their networks (Piro et al. 2016).

A core/periphery structure therefore tends to characterize also the EU innovation networks. Network structures generally coincide with the socioeconomic characteristics of regions (i.e. more advanced, innovative and competitive regions make up network cores; Calignano 2014; Calignano 2017). Innovation activities funded under the FPs are mainly concentrated in more advanced EU regions (Hoekman et al. 2013; Calignano & Hassink 2016; Dotti & Spithoven 2017). Successful applicants typically have a strong scientific reputation and previous experience from participating in

EU framework programmes (Enger & Castellacci, 2016). Norway is rarely part of this core (Barber & Scherngell 2013). Norwegian participation tends to follow the same patterns as other peripheral countries, linking frequently to core countries (Piro et al. 2016).

### *4.2. How will environmental programmes mobilise Norwegian regions?*

We expect two different influences on the spatial distribution of EU funding for green innovation: First, the need to address grand challenges and the spatially embedded nature of these challenges would mobilise regions where the need for restructuring is more severe. Second, the competition for research funding would imply that regions with strong research capacity are in a better position to attract funding. This also has implications for path development. Funding directed towards firms in related industries that need to restructure, mainly supports branching. Meanwhile, funding for regions with strong research capacity, possibly directed towards research establishments in these regions, can mainly support new path creation. As the chances of successfully restructuring are higher with a branching approach (Neffke et al. 2011; Boschma et al. 2013), the latter would be a risky strategy for restructuring. If regional industry is not involved in the project, research establishments may become 'cathedrals in the desert' that struggle to disseminate technologies.

The introduction raised three key questions: Which regions participate in the programmes? Which international networks do they establish? And are there differences in which types of organisations participate?

We expect the most developed core regions to participate more frequently. This follows past research showing that such regions attract the majority of the EU funds (Hoekman et al. 2013; Calignano & Quarta 2015). Furthermore, we expect research capacity and the need for restructuring to be important drivers of participation, reflecting path creation and branching, respectively. Second, we expect regions to connect mainly to core EU regions, following the core/periphery structure of the EU FPs (Balland et al. 2013). For path creation, leading European university regions would be important partners. For branching, connecting to regions with related knowledge capacities would be important. Finally, some studies highlight that research establishments occupy a central position in the European R&D network (Roediger-Schluga & Barber 2008), while others argue that private companies represent more relevant nodes, especially in core regions (Calignano 2017). The former would be more important for path creation, while the latter are more important for branching.

## 5. The geographical context: Greening the Norwegian economy and restructuring southwestern counties?

Norway is facing a pressing need to restructure the economy from its reliance on oil and gas exports. The long-term challenges of the greening of the economy imply lower demand for these exports in the future. However, recent short-term developments made the issue more acute. The 2014 drop in oil and gas prices had a negative impact on the economy. The Central Bank notes that "the Norwegian economy is facing new challenges. Vulnerabilities established during the golden years must be addressed. From being in a unique economic position, Norway is now headed for a period of restructuring" (Norges Bank 2015). Technological overlap between oil and gas and renewable energy suggests that there is potential for branching towards greener industries, and firms in the oil and gas industry are to some extent diversifying towards renewable energy (Steen and Weaver 2017; Mäkitie et al. 2018a).

We focus on Rogaland, Hordaland and Sør-Trøndelag. While similar in population size and position in the urban hierarchy, they differ in their dependence on oil and gas, as well as in the strength of their R&D systems (Gunnes et al. 2017). Analysing their presence in the EU's environmental programmes and their international networks, can provide an indication of how international green innovation policy mobilises actors in different types of regions.

In 2014, around 330,000 people – 13% of the workforce – worked in activities directly or indirectly related to petroleum. Rogaland (99,200) and Hordaland (56,700) accounted for nearly half of this, corresponding to 40% and 21% of their workforce, respectively. Sør-Trøndelag (10,300 or

6%) had a much lower level of petroleum-related employment (aøø figures from Blomgren et al. 2015). Rogaland and Hordaland were also hit harder by the fall in oil prices. From 2008 to 2016, unemployment grew from 1.1% to 4.5% in Rogaland and from 1.6% to 3.4% in Hordaland, but only from 2.0% to 2.3% in Sør-Trøndelag (Statistics Norway, 2017).

Norway is characterised by a strong concentration of R&D activities. In 2015, four counties (Oslo, Sør-Trøndelag, Akershus and Hordaland) accounted for 70% of R&D expenditures and 78% of university R&D (Gunnes et al. 2017). Total R&D investments in Rogaland are less than half of those in Hordaland and a third of those in Sør-Trøndelag. Sør-Trøndelag had the highest R&D investments per capita of any Norwegian county in 2015, at NOK 31,227, compared to NOK 13,267 in Hordaland and NOK 7,046 in Rogaland (Gunnes et al. 2017).

The Norwegian government has established several innovation policy programmes to support the transition towards a green economy. This includes support for environmental technology by Innovation Norway, the establishment of an investment company for renewable energy technology, and the establishment of research centres for environment-friendly energy research (Government of Norway 2017). Nonetheless, the amount spent on petroleum-related R&D was more than three times higher than that spent on R&D for renewable energy in 2015 (Engedal et al. 2017). In the two major environmental programmes funded by the RCN over the years 2014–2017 (Klimaforsk and Energix), Sør-Trøndelag was highly successful in attracting funding (637.4 million NOK; i.e. 70.8 million Euros). Despite their restructuring needs, Hordaland and Rogaland performed much worse. Hordaland attracted 67.1 million NOK (7.1 million Euros) and Rogaland only 12.3 million NOK (1.3 million Euros)[1]. Furthermore, six of the 11 research centres for environment-friendly energy research are located in Sør-Trøndelag (four at NTNU and two at SINTEF), while the remaining five are located in Oslo/Akershus.

[1] See the RCN website for further details: https://www.forskningsradet.no/prosjektbanken.

## 6. Data and methods

The study covers FP6 (2002–2006), FP7 (2007–2013) and Horizon 2020 (2014–2020) to identify potential changes over time in participation levels and network formation. In each FP, we examine the main green innovation programme: The sustainable development programme in FP6, and the environment and energy programmes in FP7 and Horizon 2020[2]. We include all projects funded by the programmes which involve at least one Norwegian partner organisation. For all partners, we code their location (by Norwegian county or EU NUTS2 region) and the type of organisation (higher education establishment, research institute, private company, public organisation, government, or other organisation). Information on the type of organisations is available only for FP7 and H2020.

First, we examine which regions participate most frequently in the programme in a regression analysis. We combine data on FP participation with Statistics Norway data on oil and gas employment and data on regional research FTEs from NIFU. Oil and gas employment is a proxy for the regional need for restructuring. Regions with a high share of employment in oil and gas face stronger pressures to restructure towards green industries. This variable may also capture other influences, such as firms' resource endowment, but it is the best available measure of restructuring need. Research FTEs is a proxy for the region's research capacity.

We construct a panel data set of 18 counties[3] over 10 years (N=180), from 2004 to 2014. We control for population size and regional GDP per capita, and fit the following logit regression model:

$$
\begin{aligned}
Logit(P(Participation_{rt} = 1 \mid x)) \\
&= Research\,FTEs_{r\,t-1} + Oil\ dependence_{r\,t-1} + Size_{r\,t-1} \\
&\quad + GDP\ per\ cap_{r\,t-1} + \tau + \varepsilon
\end{aligned}
$$

[2] The following themes were included in the analysis: FP6 Sustainable Development, FP6-SUSTDEV, and FP7 and H2020 Environment and Energy, FP7 ENVIRONMENT/H2020-ENVIRONMENT and FP7-ENERGY/H2020-ENERGY. These programmes address similar topics, such as renewable energy, environmental technology, etc., reflecting continuity in EU environmental policy.

[3] Vest-Agder and Aust-Agder are considered as one region in this analysis, because data on regional research capacity is only available for these counties jointly.

This model analyses whether or not region r starts participating in a new project in year t as a function of four factors: Research FTEs is the number of full-time equivalents (FTEs) working in research in the county. Oil dependence is the share of employees working in the oil industry. Size is the number of inhabitants. GDP per cap is the regional GDP per capita. We also include dummy variables for each year, $\tau$, and an error term, $\varepsilon$. The dependent variable is binary, all continuous variables are log-transformed, ln(var+1), and we use robust standard errors. All controls are lagged one period. We subsequently extend the analysis with a multinomial logit regression to also consider participation levels. Due to the heavily skewed distribution of the number of projects, we use a categorical variable distinguishing between regions that do not participate, and regions with low (1–3 projects), medium (4–7 projects), and high participation (8 or more projects), respectively. Year dummies are dropped from this analysis because of the limited number of observations in each group.

Second, we examine the networks which these regions create in the programme, using social network analysis techniques. These analyses build on a complete network of all Norwegian counties' participation. A link means that the counties collaborated in the same project. Since we did not map the linkages between the other EU regions, this is an ego-network[4] analysis for all Norwegian counties. We analyse regional, national and international connections to determine the geography of linkages. We focus specifically on whether differences in the research capacity of Rogaland, Hordaland and Sør-Trøndelag influences the participation of organisations in these regions. Regions with leading research organisations may connect more easily to the EU collaboration network, but may also struggle to develop links to industry and other user partners.

The analysis does not consider other important factors promoting 'green' restructuring in Norway (e.g. alternative national funding schemes, increase in internal R&D expenses, new firm births in the 'green' sector, etc.). However, the previous section discusses the volume and geographical distribution of national funding in this field. We have no information on the contents of

[4] An ego-network is a network based on the connections from a single node ("ego") (Hanneman & Riddle 2005).

the projects, or their success. Hence, we do not know to what extent they actually promote green restructuring, but can only assess their potential.

Furthermore, only partial data is available for the ongoing H2020 program, specifically for the 2014-2017 period. This allows us to assess changes in participation following the oil crisis from 2014. While the lapse of time is limited, several projects started in 2015 and 2016, allowing some time to build research groups, submit applications and start the projects. We count projects in their start year, giving time for projects to emerge. Norwegian oil companies respond quickly to market changes by reorienting towards new markets. For instance, the number of engagements in offshore wind doubled from 2014 to 2015 as the oil price fell (Mäkitie et al. 2018b). Uncertainties within the oil and gas sector influence their interest in new sectors (Steen and Weaver 2017). Nonetheless, the results from H2020 are tentative and participation patterns may shift by the end of the programme.

## 7. Norwegian organisations in the environmental programmes

Overall, Norwegian organisations participate frequently in all the programmes considered (Table 1). The share of Norwegian participation is similar in other programmes, such as FP6-SME and FP7-SME (Calignano & Hassink 2016). Surprisingly, the share of Norwegian organisations involved dropped from 3.1% in FP6 and FP7 to only 2.0% in H2020. Seemingly, the recent oil price decline did not trigger any immediate increase in Norwegian participation in programmes for green restructuring. This is contrary to the expectation based on Geels and Schot (2007) that the external shock of the oil price decline would direct more resources towards green restructuring.

[Table 1 about here]

Table 2 shows that research establishments (universities, HES, and research centres, REC) make up 72% of the Norwegian organisations involved in FP7 and 58% in H2020. Private companies are much less involved (22.5% in FP7 and 24.7% in H2020), whereas the involvement of public bodies increased from FP7 to H2020 (from 4.3% to 16.7%). The involvement of private companies is considerably higher in core European countries, especially in H2020. The environment and energy programmes have to a lesser extent mobilised industrial actors in Norway than in many other countries. Instead, they have mainly mobilised Norwegian research establishments. Norwegian public sector participation is also comparatively high. Hence, the implementation of the programme in Norway is more suited for path creation than branching, as it relies on new research findings to lead green technology development.

[Table 2 about here]

### *7.1. Which regions participate in the programmes?*

Table 3 shows the results of the regression analysis examining which regions participate in the programme. Model 1 includes the total research FTEs, whereas Model 2 splits research FTEs into FTEs in research establishments and in industry. Participation is significantly and positively associated with region size and oil dependence. Research capacity overall does not significantly affect the likelihood of participation. However, research FTEs in research establishments are strongly positively related to participation (Model 2). Meanwhile, research FTEs in industry has no significant effect on participation.

[Table 3 about here]

Table 4 shows the results of the multinomial regression analysis. There are some differences between the factors influencing participation in general and participation at high levels. In this analysis, we only show the results from Model 2, splitting research FTEs into research establishments and industry. The appendix shows marginal effects from the analysis. The marginal effects indicate that research FTEs, in REs as well as in industry, are significantly positively associated with high participation. Furthermore, research FTEs in REs are significantly negatively associated with no participation, while research FTEs in industry are negatively associated with low participation. Oil dependence is significantly negatively associated with no participation, and positively (at the 10 percent level) with medium participation, but not with high participation.

[Table 4 about here]

These results support the expectation that regional research capacity and need for restructuring are associated with participation in the programmes. For research capacity, participation is mainly driven by capacity in research establishments, rather than industry. However, research capacity in industry is associated with high participation. Overall, this supports Enger and Castellacci's (2016) finding that scientific reputation is important for attracting EU funding. Regions with a higher restructuring need are able to attract funding for restructuring projects, albeit not at the highest levels. Hence, the distribution of projects reflect both potential for branching and path creation, with the latter being most frequent.

### *7.2. Connections established by Norwegian organisations: An ego-network analysis*

Table 5 presents the social network analysis of Norwegian counties' participation. Their innovation network in FP6 has low density[5] (0.015, i.e. 1.5% of potential connections). This is reasonable as it is an ego-network, and also suggests that Norwegian regions combined were able to connect with many different regions through the programme. Overall, 16 Norwegian counties and Svalbard were active in FP6, establishing linkages with 254 different European NUTS2 regions and 38 non-EU countries. On average, each participating county connected to 4.8 other regions. Organisations in the core regions, such as Oslo, Akershus, Sør-Trøndelag and Hordaland, participated the most. Their partners were also often core regions, typically capital regions. Hence, participation patterns follow a core-periphery structure. However, the specific regional profiles associated with path creation

[5] Density is the total number of linkages in the network divided by the possible number of linkages (Hanneman & Riddle 2005).

(leading university regions) or branching (regions with specific complementary knowledge capacities) do not show up prominently in the network. The network structure remains largely the same in the FP7 network.

Norwegian participation is lower in H2020 (see also Table 1). Three years after the launch of H2020, the network density and the average number of links have dropped from FP6 and FP7. The number of participating counties has also fallen. This may still change when the programme funds more projects. However, fewer Norwegian counties are so far able to engage in the green restructuring programmes in H2020 than in previous FPs, and their international networks are less extensive. Hence, the drop in oil prices has not triggered any immediate increase in networking activities through the programme.

Among our case regions, Sør-Trøndelag and - to a lesser extent – Hordaland are among the most active counties. Conversely, Rogaland's participation is more limited. The economic shock caused by the oil price decline did not provoke major changes in this.

[Table 5 about here]

### *7.3. Types of organisations involved*

Besides the differences in participation levels, the types of organisations involved also differ between Sør-Trøndelag, Hordaland and Rogaland. Private companies are the most active organisations in Rogaland in all the FPs. In FP6, private companies represent 17 out of 24 cases. The share of private firms is also high in FP7 and H2020 (18 of 24 in FP7 and 7 of 12 in H2020). The national oil company Statoil (now Equinor) was the most active organisation with 10 participations in FP6 and 17 in FP7, but only 3 in H2020. The participation of the REs in Rogaland is limited. The University of Stavanger participated twice and the research institute IRIS six times altogether.

[Table 6 about here]

Conversely, the University of Bergen and other research establishments are the most active organisations in Hordaland. They account for 21 of 32 participations in FP6. This share further increases from FP6 to the two other FPs considered: 39 of 42 in FP7, and 21 of 24 in H2020. Hordaland shows a very different pattern from Rogaland, relying much more on research establishments and hardly on private firms.

[Table 7 about here]

Sør-Trøndelag's participation has a similar profile to that of Hordaland. In FP6, 68 of 85 participations saw the presence of NTNU or other research establishments. This share considerably increased in FP7, when the number of participations of such organisations was 100 of 104. Similarly, research establishments made up 40 of 43 participations in H2020. As in Hordaland, the number of private firms decreased in later programmes compared with FP6. Rogaland was one of the regions with which Sør-Trøndelag collaborated the most in FP6 and FP7. Collaborations between private firms in Rogaland and research establishments in Sør-Trøndelag can explain this. It reflects the pattern described by Narula (2002) of private firms in dominant industries collaborating with leading national research institutions.

[Table 8 about here]

Overall, there are differences in how Norwegian counties engage with the EU's restructuring programmes. In counties with strong research establishments, participation in the programmes takes place mainly through these organisations. Indeed, in both Hordaland and Sør-Trøndelag, research establishments have become increasingly dominant over time. In these regions, the programmes can mainly foster new path creation through scientific breakthroughs and commercialisation of research. However, a more industrial county such as Rogaland, where the need for restructuring is pressing, is able to engage with the programme in other ways. Here, industry has a much more central role, including large firms in incumbent industries acting as gatekeepers. These create larger opportunities for bricolage and branching in such regions, as knowledge from international networks can be combined with existing industrial knowledge to create new combinations. Of course, this potential can only be realized if the firms that do participate in the programme, especially from incumbent industries, transform their activities and develop new business models.

Among the three counties, Sør-Trøndelag participated in the largest number of projects, while Rogaland participated the least. Hence, EU funding more strongly mobilised counties with more mature R&D systems. The greater transition challenges in Rogaland is not sufficient to mobilise participation. Research establishments in Rogaland, being smaller and less mature, have hardly participated at all in these programmes. This has left participation largely up to private companies in Rogaland, who have mainly linked up with research establishments outside the region.

## 8. Discussion of the results

This paper has examined Norwegian counties' participation in the three most recent FPs specifically addressing environmental issues. Participation is mainly associated with research capacity at universities and research institutes. As in other EU FPs, scientific excellence attracts funding (Enger and Castellacci 2016). Oil and gas employment is also associated with participation, potentially reflecting that regions facing large restructuring challenges mobilise for these programmes. Hence, participation patterns reflect the potential for branching as well as new path creation. Norwegian regions mainly link up to core EU regions, following the core-periphery structure identified in other EU programmes (Balland et al. 2013). The projects mainly involve research establishments in counties with higher research capacity (e.g. Sør-Trøndelag and Hordaland), but private firms in more oil-dependent regions (e.g. Rogaland). Hence, the implementation of green restructuring policy differs depending on the regional context. It follows a more R&D-oriented approach based on path creation in regions with a strong initial endowment of research capacity. In regions facing major restructuring challenges, the result is a more industrially based approach aiming for branching, involving firms as the main actors (Martin 2010; Tödtling and Trippl 2013; Isaksen 2015). However, the former dominates in terms of the number of projects.

This has the potential to develop niches outside the current socio-technical regime. However, it also risks reinforcing existing patterns and may delay the transition of more oil-dependent regions into the green economy. The net effect might be a slower transition of the Norwegian economy as a whole, or the oil-dependent regions might be left behind and further locked-in to path extension. Meanwhile, the promotion of path creation through basic research is a high-risk strategy which may fail to produce substantial changes throughout the economy (Neffke et al. 2011; Boschma et al. 2013). When research establishments dominate, the opportunities for bricolage (Garud and Karnøe 2003) are limited and technological change may fail to produce broader changes in the socio-technical regime (Geels and Schot 2007; Markard and Truffer 2008).

This raises the question of how Norwegian innovation policy can be adjusted to complement EU policy and enable Norwegian organisations to benefit more from EU policy instruments. There is a need for instruments that target firms and industrial actors, moving away from the current reliance on universities to drive the transition towards a greener economy. This requires a combination of approaches: First, policy must support the R&D capacity of Norwegian firms to enable them to participate in the programmes. Norwegian domestic innovation policy prioritizes collaboration to the detriment of internal knowledge development in companies, with the effect of reducing companies' capacity to collaborate meaningfully in R&D projects (Herstad et al. 2010). This lack of capacity makes it hard for them to collaborate at a distance (de Jong and Freel 2010) and to engage in international innovation programmes, as the results in this analysis reflect.

Second, Norwegian universities need incentives and assistance to identify suitable industrial partners and include them in their consortia (Piro et al. 2016). The universities are already highly embedded in the programme and can provide firms with access to their networks (Benneworth and Hospers 2007). This will also provide them with a route to impact. The combination of these two factors can help bring the participation levels of Norwegian firms up towards those of other countries.

Third, Norwegian policy-makers must also look beyond R&D to identify mechanisms that make it attractive for non-R&D-active firms to invest in green restructuring. Norwegian restructuring policy tends to be R&D-focused and often does not fit firms with more experience-based approaches to innovation (Steen and Hansen 2018). Policies to support branching from existing industries are essential for path diversification in Norwegian regions (Brekke 2015).

Overall, this also involves lessons for policies to support green restructuring more broadly. The analysis highlights the tensions between branching and path creation (Martin 2010; Isaksen 2015) – or between breakthrough and bricolage (Garud and Karnøe 2003) – in green restructuring policies. So far, the restructuring debate has not incorporated perspectives from evolutionary economic geography to a great extent (Hansen and Coenen 2015; Boschma et al. 2017) and the roles of branching and new path creation in fostering restructuring are somewhat unclear. Yet, policy to support restructuring must strike the right balance between these two processes. Restructuring policies that place too much faith in path creation through basic and applied science may struggle to mobilise actors in peripheral regions or regions without a strong science base (Tödtling and Trippl 2005; Isaksen et al. 2018). They may also fail to reach out to industry. There is therefore a need to think seriously about how processes of regional branching and path diversification can be unleashed in the pursuit of green restructuring.

## 9. Conclusions

This study has examined the participation of Norwegian counties in the EU environmental programmes. It has analysed the organisations involved and the characteristics of their international networks with the aim of revealing how regional R&D capacity and need for restructuring influence participation. Regions with higher R&D capacity, such as Sør-Trøndelag and - to a lesser extent – Hordaland, are more active than more oil-dependent regions, such as Rogaland. Finally, and perhaps more interestingly, the types of organizations involved differ depending on the characteristics of the regions under analysis. Research establishments dominate in regions with the most developed R&D system, private companies are more involved in oil-dependent regions. Hence, the implementation of the programme depends on regional characteristics, resulting in different potentials for stimulating new path development. In research-intensive regions, the programme can mainly foster green restructuring through new path creation. In regions with a greater need for restructuring, the potential for branching is higher.

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| | FP6 - SUSTDEV | | | FP7-ENVIRONMENT/ENERGY | | | H2020 ENVIRONMENT/ENERGY | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Participation | | | Participation | | | Participation | |
| | COUNTRY | Freq. | Percent | COUNTRY | Freq. | Percent | COUNTRY | Freq. | Percent |
| 1 | Germany | 1619 | 15.2 | Germany | 1419 | 12.6 | Germany | 854 | 11.4 |
| 2 | United Kingdom | 1009 | 9.5 | United Kingdom | 1202 | 10.7 | Spain | 826 | 11.1 |
| 3 | France | 975 | 9.2 | Spain | 948 | 8.4 | Italy | 723 | 9.7 |
| 4 | Italy | 845 | 8.0 | Italy | 886 | 7.9 | United Kingdom | 722 | 9.7 |
| 5 | Netherlands | 711 | 6.7 | France | 871 | 7.7 | France | 497 | 6.7 |
| 6 | Spain | 602 | 5.7 | Netherlands | 856 | 7.6 | Netherlands | 476 | 6.4 |
| 7 | Belgium | 467 | 3.0 | Belgium | 548 | 4.9 | Belgium | 404 | 5.4 |
| 8 | Sweden | 433 | 4.1 | Sweden | 368 | 3.3 | Austria | 255 | 3.4 |
| 9 | Greece | 351 | 3.3 | *Norway* | *346* | *3.1* | Sweden | 233 | 3.1 |
| 10 | Denmark | 337 | 3.2 | Switzerland | 332 | 2.9 | Greece | 224 | 3.0 |
| 11 | *Norway* | *324* | *3.1* | Austria | 330 | 2.9 | Portugal | 219 | 2.9 |
| 12 | Austria | 319 | 3.0 | Denmark | 325 | 2.9 | Denmark | 214 | 2.9 |
| 13 | Poland | 284 | 2.7 | Greece | 300 | 2.7 | Finland | 175 | 2.3 |
| 14 | Switzerland | 265 | 2.5 | Portugal | 238 | 2.1 | Switzerland | 162 | 2.2 |
| 15 | Finland | 211 | 2.0 | Finland | 203 | 1.8 | *Norway* | *150* | *2.0* |

Table 1. Total number of participations in FP6, FP7 and H2020

| | | GOV | HES | OTH | PRC | PUB | REC | Total |
|---|---|---|---|---|---|---|---|---|
| **Norway** | *FP7* | - | 70 (20.2%) | 4 (1,2%) | 78 (22.5%) | 15 (4.3%) | 179 (51.7%) | 346 (100%) |
| | *H2020* | - | 28 (18.7%) | 1 (0.7%) | 37 (24.7%) | 25 (16.7%) | 59 (39.3%) | 150 (100%) |
| **Germany** | *FP7* | - | 322 (22.7%) | 76 (5.4%) | 433(30.5%) | 31 (2.2%) | 557 (39.3%) | 1419 (100%) |
| | *H2020* | - | 127 (14.9%) | 98 (11.5%) | 335 (39.2%) | 38 (4.4%) | 256 (30.0%) | 854 (100%) |
| **UK** | *FP7* | 29 (2.4%) | 577 (57.6%) | 43 (3.6%) | 293 (23.4%) | 75 (6.2%) | 185 (15.4%) | 1202 (100%) |
| | *H2020* | 16 (2.2%) | 223 (31.0%) | 82 (11.4%) | 289 (40.0%) | 52 (7.2%) | 60 (8.3%) | 722 (100%) |
| **Spain** | *FP7* | - | 179 (18.9%) | 19 (2.0%) | 351 (37.0%) | 61 (6.4%) | 338 (35.7%) | 948 (100%) |
| | *H2020* | - | 90 (10.9%) | 52 (6.3%) | 349 (42.3%) | 107 (13.0%) | 228 (27.6%) | 826 (100%) |
| **Italy** | *FP7* | 8 (0.9%) | 220 (24.8%) | 15 (1.7%) | 270 (30.5%) | 57 (6.4%) | 316 (35.7%) | 886 (100%) |
| | *H2020* | 4 (0.5%) | 129 (17.8%) | 50 (6.9%) | 320 (44.3%) | 76 (10.5%) | 144 (19.9%) | 723 (100%) |
| **Netherlands** | *FP7* | - | 246 (28.7%) | 94 (11.0%) | 257 (30%) | 51 (6.0%) | 208 (24.3%) | 856 (100%) |
| | *H2020* | - | 88 (18.5%) | 63 (13.2%) | 197 (41.4%) | 51 (10.7%) | 77 (16.2%) | 476 (100%) |

Table 2. Type, number and share of participations (Norway and top-five countries in FP6, FP7 and H2020. Legend: GOV - Government, HES - Higher education establishments, OTH - other, PRC - private for profit companies, PUB - public organisations, REC - research institutes

| | (1) | (2) |
|---|---|---|
| Research FTEs | 0.583 | |
| | (0.451) | |
| Research FTEs in research establishments | | $0.932^{***}$ |
| | | (0.252) |
| Research FTEs in industry | | -0.418 |
| | | (0.275) |
| Oil dependence | $0.281^{**}$ | $0.451^{***}$ |
| | (0.133) | (0.156) |
| Population size | $1.381^{*}$ | $2.591^{***}$ |
| | (0.812) | (0.912) |
| Regional GDP per capita | 1.676 | -0.800 |
| | (1.845) | (1.891) |
| Year controls | YES | YES |
| Constant | $-42.81^{*}$ | -26.96 |
| | (24.17) | (19.25) |
| pseudo $R^2$ | 0.380 | 0.427 |
| $N$ | 180 | 180 |

Table 3. Factors influencing participation of the Norwegian regions. Logit regression model. Standard errors in parentheses. Significance level: $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

| | Participation (baseline: no participation) | | |
|---|---|---|---|
| | Low | Medium | High |
| Research FTEs in research establishments | 0.659** | 3.211*** | 5.581*** |
| | (0.287) | (0.872) | (1.646) |
| Research FTEs in industry | -0.342 | 4.975** | 9.031*** |
| | (0.249) | (2.036) | (2.288) |
| Oil dependence | 0.388** | 2.222*** | 2.547*** |
| | (0.153) | (0.773) | (0.931) |
| Population size | 2.206*** | -10.11* | -16.60*** |
| | (0.836) | (5.625) | (6.285) |
| Regional GDP per capita | -2.171* | -5.843** | -10.43*** |
| | (1.143) | (2.736) | (3.495) |
| Constant | -4.164 | 133.5** | 228.4*** |
| | (12.97) | (63.39) | (72.88) |
| pseudo $R^2$ | | 0.519 | |
| *N* | | 180 | |

Table 4. Factors affecting participation levels of the Norwegian regions. Multinomial logit regression model. Standard errors in parentheses. Significance level: * p < 0.10, ** p < 0.05, *** p < 0.01

| NORWAY | | | | | | |
|---|---|---|---|---|---|---|
| | **FP6** | | **FP7** | | **H2020** | |
| **Active Norwegian counties** | 16 + Svalbard | | 15 + Svalbard | | 12 + Svalbard | |
| **Active EU NUTS2 regions** | 254 | | 210 | | 176 | |
| **Active non-EU countries** | 38 | | 50 | | 24 | |
| **Density** | 0.015 | | 0.017 | | 0.008 | |
| **Average number of links** | 4.8 | | 4.7 | | 3.0 | |
| **Degree centrality** | **Region** | | **Region** | | **Region** | |
| ***Out-degree*** | Oslo | 1862 | Oslo | 1514 | Oslo | *747* |
| | Akershus | 1588 | *Sør-Trøndelag* | *1358* | *Sør-Trøndelag* | *489* |
| | *Sør-Trøndelag* | *1265* | Akershus | 1229 | *Hordaland* | *380* |
| | *Hordaland* | *785* | *Hordaland* | *642* | Akershus | 339 |
| | *Rogaland* | *542* | *Rogaland* | *561* | Rogaland | 113 |
| | Troms | 430 | Troms | 281 | Troms | *104* |
| ***In-degree*** | | | | | | |
| ***Norway*** | Sør-Trøndelag | 122 | *Sør-Trøndelag* | 96 | *Hordaland* | 42 |
| | Oslo | *92* | *Oslo* | *82* | *Oslo* | *26* |
| | Akershus | 75 | Akershus | 75 | *Akershus* | *23* |
| | *Hordaland* | *74* | *Hordaland* | *50* | *Sør-Trøndelag* | 20 |
| | *Rogaland* | *72* | *Rogaland* | *46* | *Rogaland* | 10 |
| ***EU NUTS2*** | Île de France | 453 | Île de France | 317 | Île de France | 100 |
| | South-Holland | 211 | South-Holland | 170 | Lazio | 80 |
| | Lazio | 176 | Brussels | 153 | Madrid | 74 |
| | Brussels | 163 | Lazio | 149 | Brussels | 72 |
| | Attika | 159 | Madrid | 139 | Catalonia | 61 |
| | Madrid | 146 | London | 137 | South-Holland | 58 |
| | London | 143 | Midtjylland | 123 | Lisbon | 46 |
| | Hamburg | 143 | Oberbayern | 116 | Helsinki | 45 |
| | Copenhagen | 137 | Swindon/Wiltshire | 113 | Copenhagen | 43 |
| | Helsinki | 129 | Catalonia | 97 | London | 38 |
| ***Other countries*** | Russia | 89 | Russia | 43 | Russia | 21 |
| | China | 60 | Turkey | 41 | USA | 19 |
| | Turkey | 53 | USA | 38 | Turkey | 15 |
| | India | 32 | Canada | 30 | Canada | 13 |
| | USA | 29 | Israel | 29 | China | 10 |
| **Betweenness** | Sør-Trøndelag | 850 | Sør-Trøndelag | 1094 | Oslo | 626 |
| | Akershus | 796 | Oslo | 899 | Sør-Trøndelag | 453 |
| | Oslo | 649 | Akershus | 538 | Hordaland | 316 |
| | Hordaland | 370 | Hordaland | 298 | Akershus | 277 |
| | Aust-Agder | 144 | Rogaland | 212 | Rogaland | 68 |

Table 5. Linkages in FP6, FP7 and H2020. In-degree: Collaborations between Norwegian counties, and NUTS2 regions and extra-EU countries. Out-degree: Number of projects and collaborations with partners in other NUTS2 regions and extra-EU countries of the participating Norwegian counties. Out-degree is the number of linkages from one specific node to other nodes, while in-degree is the number of linkages from other nodes to a specific node.

| ROGALAND - ego-network | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **FP6** | | | | | **FP7** | | | | | **H2020** | | | | |
| **No of participations** | 24 | | | | | 24 | | | | | 12 | | | | |
| **No of projects** | 18 | | | | | 22 | | | | | 7 | | | | |
| **Connected to…** | | | | | | | | | | | | | | | |
| **Other Norwegian counties** | 8 + Svalbard | | | | | 8 | | | | | 4 | | | | |
| **EU NUTS regions** | 96 | | | | | 104 | | | | | 58 | | | | |
| **Non-EU countries** | 11 | | | | | 6 | | | | | 0 | | | | |
| **Degree centrality** | **Region** | **Links** | | | | **Region** | **Links** | | | | **Region** | **Links** | | | |
| | | **SUM** | **RES/ HES** | **PRC** | **PUB /GOV** | | **SUM** | **REC /HES** | **PRC** | **PUB GOV** | | **SUM** | **REC /HES** | **PRC** | **PUB /GOV** |
| ***LINKS - OUT*** | In Rogaland | | 2 | 20 | 2 | In Rogaland | | 3 | 17 | 4 | In Rogaland | | 3 | 7 | 2 |
| ***Links - TO*** | From Rogaland | 542 | | | | From Rogaland | 561 | **222** | **126** | **41** | From Rogaland | 113 | **38** | **51** | **21** |
| ***Norway*** | Sør-Trøndelag | 30 | 25 | 5 | 0 | Sør-Trøndelag | 16 | 15 | 1 | 0 | Akershus | 4 | 3 | 1 | 0 |
| | Oslo | 9 | 5 | 1 | 3 | Oslo | 6 | 1 | 3 | 2 | Østfold | 2 | 1 | 1 | 0 |
| | Hordaland | 6 | 4 | 2 | 0 | Akershus | 6 | 3 | 3 | 0 | Oslo | 1 | 1 | 0 | 0 |
| ***EU NUTS2*** | Île de France | 43 | No information about this in the EU-data | | | Île de France | 18 | 11 | 7 | 0 | Madrid | 6 | 2 | 4 | 0 |
| | Copenhagen | 19 | | | | Zuid-Holland | 14 | 1 | 5 | 8 | Iceland | 6 | 3 | 3 | 0 |
| | South-Holland | 19 | | | | Lazio | 13 | 7 | 6 | 0 | Oberbayern | 4 | 2 | 1 | 1 |
| | London | 18 | | | | Midtjylland | 12 | 5 | 4 | 0 | Midtjylland | 4 | 1 | 2 | 1 |
| | Attika | 15 | | | | London | 10 | 5 | 1 | 2 | Centre-Loire | 4 | 1 | 0 | 3 |
| | Swindon/Wiltshire | 13 | | | | Swindon/Wiltshire | 10 | 5 | 5 | 0 | Gelderland | 4 | 1 | 3 | 0 |
| | Lazio | 10 | | | | Oberbayern | 9 | 7 | 0 | 2 | South-Holland | 4 | 1 | 1 | 2 |
| | Brussels | 8 | | | | Eastern Scotland | 9 | 6 | 2 | 1 | Catalonia | 3 | 1 | 1 | 1 |
| ***Non-EU countries*** | China | 9 | | | | USA | 8 | 6 | 0 | 2 | | | | | |
| | Russia | 4 | | | | Canada | 4 | 4 | 0 | 0 | | | | | |

Table 6: Rogaland collaborations

**HORDALAND – ego-network**

| | FP6 | | | | | FP7 | | | | | H2020 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No of participations** | 32 | | | | | 42 | | | | | 24 | | | | |
| **No of projects** | 19 | | | | | 30 | | | | | 16 | | | | |
| **Connected to…** | | | | | | | | | | | | | | | |
| **Other Norwegian counties** | 11 + Svalbard | | | | | 7 | | | | | 7 + Svalbard | | | | |
| **EU NUTS regions** | 131 | | | | | 108 | | | | | 96 | | | | |
| **Non-EU countries** | 15 | | | | | 24 | | | | | 12 | | | | |
| **Degree centrality** | **Region** | **Links** | | | | **Region** | **Links** | | | | **Region** | **Links** | | | |
| | | **SUM** | **RES/HES** | **PRC** | **PUB/GOV** | | **SUM** | **REC/HES** | **PRC** | **PUB GOV** | | **SUM** | **REC/HES** | **PRC** | **PUB/GOV** |
| ***LINKS - OUT*** | In Hordaland | | *21* | *10* | *1* | In Hordaland | | *39* | *3* | *0* | In Hordaland | | 21 | 2 | 1 |
| ***Links - TO*** | From Hordaland | 785 | | | | From Hordaland | 642 | **488** | **74** | **74** | From Hordaland | 380 | **246** | **64** | **43** |
| ***Norway*** | Oslo | 14 | 12 | 1 | 1 | Akershus | 11 | 10 | 1 | 0 | Akershus | 8 | 4 | 3 | 1 |
| | Troms | 8 | 7 | 1 | 0 | Oslo | 7 | 6 | 1 | 0 | Oslo | 5 | 5 | 0 | 0 |
| | Sør-Trøndelag | 5 | 3 | 2 | 0 | Troms | 4 | 4 | 0 | 0 | Troms | 3 | 2 | 1 | 0 |
| ***EU NUTS2*** | Île de France | 48 | No information about this in the EU-data | | | Île de France | 50 | 41 | 4 | 5 | Île de France | 18 | 16 | 1 | 1 |
| | Bremen | 18 | | | | Devon | 23 | 13 | 0 | 10 | Catalonia | 12 | 8 | 2 | 2 |
| | Midtjylland | 18 | | | | Schleswig-Holst. | 21 | 20 | 0 | 1 | Lazio | 12 | 9 | 2 | 1 |
| | Lazio | 18 | | | | North-Holland | 21 | 20 | 1 | 0 | Madrid | 11 | 7 | 2 | 2 |
| | Athens | 17 | | | | Bremen | 19 | 17 | 2 | 0 | Lisbon | 9 | 3 | 2 | 4 |
| | Oberbayern | 17 | | | | Swindon/Wiltshire | 18 | 17 | 1 | 0 | Devon | 9 | 4 | 0 | 5 |
| | Hamburg | 16 | | | | Lazio | 17 | 16 | 0 | 1 | Bremen | 8 | 7 | 1 | 0 |
| | South-Holland | 15 | | | | London | 17 | 8 | 2 | 7 | North-Holland | 8 | 6 | 1 | 1 |
| ***Non-EU countries*** | Russia | 11 | | | | China | 6 | 5 | 1 | 0 | USA | 7 | 6 | 0 | 1 |
| | Turkey | 7 | | | | South Africa | 5 | 5 | 0 | 0 | Canada | 6 | 3 | 0 | 3 |

Table 7: Hordaland collaborations

| SØR-TRØNDELAG – ego-network | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FP6 | | | | | FP7 | | | | | H2020 | | | | |
| **No of participations** | 85 | | | | | 104 | | | | | 43 | | | | |
| **No of projects** | 56 | | | | | 82 | | | | | 35 | | | | |
| **Connected to…** | | | | | | | | | | | | | | | |
| **Other Norwegian counties** | 12 + Svalbard | | | | | 12 | | | | | 7 | | | | |
| **EU NUTS regions** | 171 | | | | | 161 | | | | | 128 | | | | |
| **Non-EU countries** | 19 | | | | | 26 | | | | | 12 | | | | |
| **Degree centrality** | **Region** | **Links** | | | | **Region** | **Links** | | | | **Region** | **Links** | | | |
| | | **SUM** | **RES/ HES** | **PRC** | **PUB /GOV** | | **SUM** | **REC /HES** | **PRC** | **PUB GOV** | | **SUM** | **REC /HES** | **PRC** | **PUB /GOV** |
| ***LINKS - OUT*** | In Sør-Trøndelag | | *68* | *12* | *5* | In Sør-Trøndelag | | *100* | 2 | 2 | In Sør-Trøndelag | | 40 | 2 | 1 |
| ***Links - TO*** | From Sør-Trøndelag | 1265 | | | | From Sør-Trøndelag | 1358 | 699 | 458 | 191 | From Sør-Trøndelag | *489* | **228** | **173** | **85** |
| ***Norway*** | Rogaland | 20 | 2 | 17 | 1 | Oslo | 17 | 3 | 7 | 7 | Oslo | 6 | 0 | 4 | 2 |
| | Akershus | 12 | 0 | 11 | 1 | Rogaland | 16 | 2 | 13 | 1 | Akershus | 2 | 1 | 1 | 0 |
| | Oslo | 11 | 5 | 3 | 3 | Akershus | 13 | 6 | 7 | 0 | Østfold | 2 | 1 | 1 | 0 |
| ***EU NUTS2*** | Île de France | 92 | No information about this in the EU-data | | | Île de France | 75 | 44 | 27 | 3 | Brussels | 15 | 4 | 2 | 9 |
| | Zuid-Holland | 52 | | | | Zuid-Holland | 53 | 12 | 19 | 22 | Vienna | 14 | 8 | 4 | 2 |
| | Brussels | 37 | | | | Brussels | 49 | 4 | 12 | 33 | Île de France | 14 | 6 | 5 | 3 |
| | Lazio | 37 | | | | Midtjylland | 41 | 25 | 9 | 5 | Madrid | 13 | 6 | 4 | 3 |
| | Madrid | 33 | | | | Madrid | 41 | 25 | 14 | 1 | South-Holland | 13 | 2 | 6 | 5 |
| | London | 30 | | | | London | 37 | 21 | 11 | 5 | Catalonia | 12 | 4 | 4 | 4 |
| | Attika | 28 | | | | Basque | 29 | 18 | 8 | 2 | Helsinki | 12 | 4 | 1 | 7 |
| | Hamburg | 27 | | | | Oberbayern | 26 | 21 | 2 | 3 | Lazio | 12 | 8 | 4 | 0 |
| ***Non-EU countries*** | China | 12 | | | | USA | 12 | 3 | 3 | 6 | Turkey | 4 | 2 | 2 | 0 |
| | Russia | 11 | | | | Australia | 11 | 7 | 1 | 3 | Tanzania | 4 | 4 | 0 | 0 |

Table 8: Sør-Trøndelag collaborations

| | dy/dx | Std. Err. | P>z |
|---|---|---|---|
| **Research FTEs_RE** | | | |
| No participation | -0.112 | 0.027 | 0.000 |
| Low | 0.005 | 0.039 | 0.896 |
| Medium | 0.020 | 0.037 | 0.591 |
| High | 0.087 | 0.033 | 0.009 |
| **Research FTEs_ind** | | | |
| No participation | -0.001 | 0.046 | 0.985 |
| Low | -0.202 | 0.062 | 0.001 |
| Medium | 0.051 | 0.073 | 0.487 |
| High | 0.153 | 0.047 | 0.001 |
| **Oil dependence** | | | |
| No participation | -0.067 | 0.018 | 0.000 |
| Low | 0.000 | 0.025 | 0.998 |
| Medium | 0.046 | 0.028 | 0.100 |
| High | 0.021 | 0.019 | 0.259 |
| **Size** | | | |
| No participation | -0.192 | 0.135 | 0.156 |
| Low | 0.633 | 0.179 | 0.000 |
| Medium | -0.175 | 0.215 | 0.415 |
| High | -0.266 | 0.130 | 0.042 |
| **GDP_per_cap** | | | |
| No participation | 0.327 | 0.142 | 0.021 |
| Low | -0.156 | 0.140 | 0.264 |
| Medium | -0.010 | 0.065 | 0.877 |
| High | -0.161 | 0.044 | 0.000 |

Appendix S1. Marginal effects from the multinomial logistic regression in Table 4

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