

Can small regions construct regional advantages? The case of four Norwegian regions

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Abstract

The conceptual framework of constructing regional advantage (CRA) is implicitly relevant for large, well-off regions that have strong regional innovation systems, a diversity of industrial sectors and resourceful firms that can partake in global knowledge networks. This paper discusses the extent to which small regions, with less developed regional innovation systems, may also constitute the basis for developing regional advantage. Four cases of regional industries dominated by different innovation modes make up the empirical test bed in the paper. The innovation modes are STI (Science, Technology, Innovation), CCI (Complex, Combined Innovation) and DUI (Doing, Using, Interacting). The CRA framework is found to represent a useful conceptual construct also for small regions provided some reformulations. Adapting the CRA framework to small regions involves focusing more on increasing the innovation capabilities at the firm level, placing less emphasis on the endogenous capacity of regional innovation systems – but emphasising the importance of experience-based knowledge in local labour markets – and concentrating more on the need for diversity of knowledge bases at the regional level. Policy lessons for constructing regional advantage in small regions should, in general, consider the upgrading of DUI-firms and stimulating extra-regional links.

Keywords: Constructing regional advantage, modes of innovation, related variety, regional innovation system

Introduction

The economy has certainly become more global in many respects in the last two decades. Firms increasingly source components, services and knowledge from more geographically distant partners. However, many scholars also argue that firms often gain competitiveness by employing local and regional resources and knowledge (Kitson et al. 2004, Malmberg and Power 2005).

The paper departs from the framework of constructing regional advantage (CRA) in examining the local foundation of industrial competitiveness (EC 2006, Asheim et al. 2007, 2011). The framework emphasises that regional advantage does not necessarily emerge spontaneously even in clusters of firms, rather advantages can be constructed through proactive partnership between public and private actors. It is then important to stimulate knowledge flow and interactive learning among proximate partners and, in particular, among partners with related but not similar knowledge bases (Noteboom et al. 2007, Boschma and Frenken 2011).

The CRA framework seems implicitly to fit very well large regions that have urbanisation economies, which are characterised by varied industries and a large knowledge infrastructure (McCann 2008). It is more a questionable whether regions other than such stereotypically ‘happy few’ (Asheim and Coenen 2005, p. 1181) can form the basis for regional advantage. The paper focuses on small regions characterised by small populations, a small number of firms, a narrow industrial base and few knowledge organisations, which, as a consequence, do not have a well-developed regional innovation system. Firms in such regions *may* have to bring in necessary input factors from geographically distant sources – more so than firms in bigger regions with greater resources. To what extent, therefore, is the CRA framework relevant in analyses of, and policy formulation in, small regions? If the competitiveness of firms relies only to a small degree on specific regional factors (due to a relatively small regional resource base), is it then still possible to construct regional advantage? The first research question in the paper is: How and to what extent can small regions construct regional advantage? This question concerns the relevance of the CRA framework as a conceptual construct to study aspects of industries’ competitiveness in small regions, and the relevance of the framework to formulate policy measures to strengthen the competitiveness of industries which are particularly adapted to small regions.

A key point in the CRA framework is that various types of firms, for example, those with different modes of innovation, need different kinds of support from the regional institutional and knowledge infrastructure (Asheim et al. 2007). A science based firm requires, in general, other input factors than, for example, a firm building much more on practical, experience based knowledge. Broadly speaking, the literature maintains that larger cities stimulate, in particular, firms that employ science based knowledge in radical innovation processes, while assets in smaller cities stimulate firms that compete through incremental, market based innovations (e.g. Therrien 2005). This reflects the fact that assets in small regions may trigger the competitiveness of some types of firms but not others. There is, however, a need for more knowledge about what type of firms can contribute to competitive advantages in small cities and regions with weak regional innovation systems (RIS). Such knowledge may provide insight into how regional advantages can be constructed in small regions, among other things the key target group of firms for policy measures. The second

research question is therefore: What types of firms contribute in particular to constructing regional advantage in small regions?

The paper consists of three main parts. The first part discusses the main building blocks in the framework of regional advantage, and considers the opportunities and limits of small regions with weak RIS to construct regional advantages. The second part analyses the situation in terms of four empirical cases of the use of CRA framework and describes the context and empirical investigations carried out. The cases include four regional industries in Norway: the marine biotechnology industry in Tromsø, the electronics industry in Horten, the production of lightweight material goods in Raufoss and the oil and gas equipment supplies industry in Agder. The industries are found along the continuum from the typical science based marine biotechnology to the mainly practical, experience based oil and gas equipment suppliers. Finally, the third part of the paper examines the extent to which the CRA framework represents a useful conceptual construct in analyses of industrial competitiveness in small regions.

Construction of regional advantage

It is a well known fact that firms, particularly those in high cost locations, have to differentiate themselves from their competitors. A key competitive advantage is the unique competence of firms that cannot easily be copied by others. Such advantage is maintained and extended through continuous innovation activities which often will include the learning of new skills (Lorenz and Valeyre 2006). It is also generally accepted that firms almost never innovate in isolation (Fagerberg et al. 2005). Instead, they acquire complementary, external knowledge, and engage in interactive learning processes with dedicated partners. They also manage to integrate internal and external flows into a coordinated innovation process (Lundvall 2007).

External partners and knowledge can be found in many, and distant, places. However, certain types of cooperation in innovation processes take place more easily, and certain types of knowledge flow are facilitated by face-to-face meetings and co-presence of partners (Gertler 2007). This is particularly the case as regards complex innovation activities and the exchange of tacit knowledge. It is also known that geographical proximity may stimulate cognitive, social and cultural proximity (Boschma 2005), which facilitate trust based cooperation, a factor of special importance under conditions of uncertainty and creativity (Storper and Venables 2004).

Here, the concept of *regional* advantage becomes relevant. The regional environment can stimulate the innovation activity of firms in two principal ways. First, regions may contribute favourable location factors, such as trained labour, specialised suppliers and research organisations, that trigger local learning processes, innovation activity and adjustment (Storper 2009). Some types of specialised information and knowledge are sticky and thus not uniformly available. Scholars maintain that “cutting-edge technology is strongly tied to the universities and research centres where it originates” (Malecki 2010: 1040), and that “the important tasks of synthesizing and integrating knowledge are not able to be located equally anywhere” (Malecki 2010: 1034). Much knowledge, therefore, has characteristics that make it very difficult to understand outside the local context in which it is generated (op. cit.). Second, socio-cultural and institutional factors can ease the diffusion and exchange of

locally based skills and knowledge among players. Geographical and other types of proximity help, in particular, the exchange of tacit knowledge (Lundvall 2007, Storper 2009).

Such arguments are well known from the cluster literature (Asheim et al. 2005), which emphasises that regional specialisation in one or a few adjacent industries and the related localisation economies stimulates productivity improvements and competitiveness in regional clusters. Some scholars, however, maintain that diversity and variety of knowledge bases and knowledge inputs are replacing specialisation as the main driver in the creation of new economic activity (e.g. Laursen and Salter 2006, Boschma and Frenken 2011). Related variety of knowledge among actors in a region – i.e. firms and knowledge organisations hold knowledge that is neither similar nor too different from each other – is seen as vital in stimulating the emergence of new industries from old industries in a region. Boschma and Frenken (2011) define the spin-off of new industries from old industries as regional branching, in which a central mechanism is the combination of existing knowledge that is turned into new productive knowledge. Regional branching based on related variety emphasises urbanisation economies, which are most pronounced in large cities, rather than localisation economies as the main driver in the creation of new industries, or new path-dependent developments (Martin and Sunley 2010).

Four building blocks of regional advantage and the relevance for small regions

The perspective of *constructing* regional advantage emphasises the fact that advantages do not necessarily emerge automatically when similar and related firms cluster in a region. Rather, regional advantages can be stimulated and constructed through active cooperation between public and private actors (EC 2006). However, activities and policy tools have to be adapted to specific conditions and challenges in different regions. No ‘one-size-fits-all’ policy prescription exists to construct regional advantage in every case (Tödting and Tripl 2005). Policy tools have to be tailor-made for specific regional circumstances, and, in particular, four factors should be considered when adapting policy, which constitute the building blocks of the perspective of constructing regional advantage (Karlsen et al. 2011).

The first building block concerns the fact that firms innovate in different ways and employ different types of critical skills and knowledge in their innovation process. In order to conceptualise the main ways in which firms organise and carry out innovation processes, we differentiate between three innovation modes: 1) Doing Using, Interacting (DUI); 2) Science, Technology, Innovation (STI) (Lorenz and Lundvall 2006, Jensen et al. 2007) and 3) Combined and Complex Innovation (CCI) (Isaksen and Karlsen 2012b).

The DUI mode of innovation is first of all based on learning from experiences and competences acquired by employees on the job as they face new challenges and problems that have to be solved. The challenges may come from the firms’ own activities, but they often relate to requirements and needs of customers and users (Lundvall 2007). The innovation process in the DUI mode mainly takes place through the daily work and results most often in incremental changes in products and ways of doing things.

The STI mode has a much stronger focus on science-based learning and R&D-activities. Much of the innovation activity takes place in in-house R&D departments, research intensive firms and universities and research institutes, with the intention of developing fairly radical innovations. The knowledge creation is in large part based on the development and

testing of formal, scientific models, and includes elements of basic research. The innovation process is more characterised by the science push rather than the market pull of the DUI mode.

The CCI mode characterises firms that in different ways link and adapt scientifically based and experience based knowledge from different sources in innovation projects. This combination of knowledge occurs when tacit knowledge is made explicit in firms and then mixed with scientific methods and knowledge both inside the firm and with external knowledge organisations (Hansen and Winter 2011; Isaksen and Karlsen 2012b). The innovations often include several incremental innovations in the same product or a new technological platform for the firm (Isaksen and Karlsen 2012a).

Firms dominated by different innovation modes may be unevenly distributed in space. This applies first of all to STI-firms (or firms in industries with comparatively high R & D-intensity), which are biased towards large cities and specialist university cities (Cooke 2002: 130-131). In such locations STI-firms have better access to researchers and research groups with new innovative ideas that have not yet been published than would be the case in smaller regions with few or no higher education institutions. Not least, STI spin-offs will tend to locate in larger cities or near universities. Entrepreneurs often have some location inertia as their start-ups are based on knowledge, experience and contacts in specific locations, and, therefore, regions with a large number of scientists and students have advantages with regard to new STI-firms (Feldmann 2007). Smaller regions are thus supposed to have comparatively few STI-firms.

Important in our context is the fact that firms and industries dominated by different innovation modes may need different types of support from the institutional and knowledge infrastructure. Demanding customers and strategic suppliers represent key external knowledge sources for DUI-firms (Jensen et al. 2007). These firms benefit then from dense contact with some customers and suppliers and from access to experience based knowledge, for example, through a local labour market. STI firms, on the other hand, acquire key, external knowledge from researchers at universities and research organisations. CCI-firms are between the STI- and the DUI-firms as they combine knowledge from demanding customers and experience based, internal knowledge with knowledge from research organisations.

A second building block, which exactly conceptualises the institutional and knowledge infrastructure, consists of the regional innovation system. A regional innovation system (RIS) is analytically divided into two subsystems (Cooke et al. 2000, pp. 104–105). The first consists of firms in the main industries or clusters in a region. The second includes the knowledge infrastructure of education and research institutions as well as technology centres, science parks, incubators and so on. Included in the RIS framework is also the importance of informal institutions and policy instruments that can facilitate knowledge flow between universities, R&D institutions and regional firms (Cooke 1998; Tödtling and Trippel 2005).

The core of the argument is that DUI-, CCI- and STI-firms rely on different external knowledge sources which typify different types of RIS. A narrow definition of RIS includes mainly R&D activities in universities, research institutes and firms' R&D departments (cf. Lundvall 1992; Lundvall 2007). The narrow RIS is first of all relevant for STI-firms that benefit from access to knowledge bases in advanced research institutes. This is indicated by Laursen and Salter (2006), who find that firms with radical innovations more often search

knowledge intensely from few partners. These may be found in different parts of the world. However, firms may also benefit from close geographical distance to some research institutes, both to gain early access to new research results and to recruit highly educated labour (Cooke 2002).

Regional innovation systems may also be defined broadly to include all the actors and activities that affect learning, knowledge creation and innovation in a region. In this respect, universities fulfil functions other than being “immediate sources of innovation”, such as educating skilled workers (Lundvall 2007, p. 97). The broad RIS relates more to the DUI and CCI modes of innovation and includes a specialised labour market, applied research institutes, non R&D-based business services and a local technical culture where knowledge is created, maintained and shared through cooperation between firms, knowledge organisations, specialised consulting firms and so on. This conceptualisation also leads to the conclusion that smaller regions with weak RIS will have problems in constructing regional advantages in industries dominated by the STI innovation mode. By definition such regions will not hold narrow RIS with considerable research organisations. Rather, small regions with weak RIS are able to support CCI- and particularly DUI-firms through an experienced labour force, non R&D-based business services, etc.

The third building block in constructing regional advantage emphasises the importance of diversity of regions’ knowledge bases. The idea is that diversity may facilitate the linking of related knowledge, which may then increase the potential for learning between firms (Noteboom et al. 2007, Boschma and Frenken 2011). Knowledge will mostly spill over between industrial sectors that are complementary in terms of knowledge (Asheim et al. 2011). The focus on diversity and related knowledge runs against the traditional view on the importance of regional clusters in which firms gain competitiveness through specialisation and localisation economies (Asheim et al. 2011). The view rather emphasises the urbanisation effects of agglomeration economies as a key in triggering innovation processes (Gordon and McCann 2005).

This also implies that related variety is primarily found in larger cities. “The higher the number of technologically related sectors in a region (...), the more learning opportunities will be available” (Asheim et al. 2011: 895), and thus more innovation activity and regional growth are expected to take place. Smaller regions, therefore, have a disadvantage with regard to related variety as these often tend to be specialised in few and mature industries (Duranton and Puga 2002). Firms in small regions may, however, bring in extra-regional, complementary knowledge, which is further discussed below along with the fourth building block of creating regional advantage.

We proposed above that small regions often have comparatively few STI-firms and then relatively many DUI- and CCI-firms. This firm structure may also contribute to low related variety in small regions. The DUI mode builds primarily on experience based knowledge. Such knowledge has important tacit elements (Gertler 2007), and is context dependent, for example, by being based on historically developed technological competence. This kind of knowledge does not travel well over geographical distances (Asheim and Gertler 2005), which consequently restricts the possibilities for knowledge flow and thus for achieving related variety. The CCI mode combines experience and research based knowledge, and this mode also contains elements that are context dependent and sticky. The STI mode, on

the other hand, builds on research based knowledge, which is often codified, making it easier to link pieces of knowledge.

The concept of related variety can be extended to include the variety of knowledge bases and innovation modes. Jensen et al. (2007) maintain that firms that combine the STI and DUI modes of innovation are more product innovative than firms relying mostly on one of the modes. This is in line with Laursen and Salter (2006), who demonstrate that firms which pursue knowledge from diverse sources are the most innovative. Again, small regions are disadvantaged as long as regional knowledge sources are considered.

In nearly all cases, however, the most important source of variety in the knowledge bases will be found outside the region (Asheim et al. 2011). Thus, the ability of firms to tap into extra-regional knowledge networks and use this productively is very important. The fourth building block relates exactly to developing the capability of firms to access and capitalise on globally distributed knowledge networks. Participation in such networks may constitute a central arena of learning for firms. Firms may benefit from expertise from many sources because relevant knowledge is increasingly diverse, complex and dispersed (Malecki 2010). However, based on empirical analyses of Italian provinces from 1995 to 2003, Boschma and Iammarino (2008) conclude that simply being well connected to the outside world or having a high variety of inflowing knowledge do not contribute to regional growth. Instead, they found evidence that related, extra-regional knowledge sparks off inter-sectoral learning across regions. Regions should, in particular, have some resourceful firms that participate in global 'learning' networks and act as nodes that import knowledge that may diffuse to other co-located firms (Giuliani and Bell 2005). Extra-regional networks can also be based on the existence of specific regional and national assets, for example, long tradition and experience in a particular production activity in a region, or high R&D activity in a specific scientific field in a region's or nation's knowledge infrastructure. Such specific assets may lead to 'strategic coupling' of regional assets and the interest of lead firms in global production networks (Coe et al. 2004). A tendency exists then for some corporations to locate in agglomerations of excellence, in order to take advantage of local dynamic learning processes (Malecki 2010).

The global knowledge networks may be different in typical DUI-, STI- and CCI-firms. The DUI-firms are often less resourceful than the other two types of firms measured, for example, in terms of the share of employees with higher education, R&D capacity and activity. Less internal resources in DUI-firms may lead to less developed external knowledge networks outside the regions.

Compared with DUI-firms, STI- and CCI-firms rely more on codified knowledge, which travels more easily in the geographical space (Asheim and Gertler 2005). Thus, they have greater opportunities for external networks and investments than the generally less resourceful DUI firms. External investments provide a platform for international cooperation and information pursuit, and where (geographical mobile) knowledge can be canalised back to the regional industry. Research also indicates that R&D-intensive firms have, to a larger extent, globalised their innovation activity (Herstad 2008). For this reason, firms with higher absorptive capacities are more likely to interconnect cognitively with external sources of knowledge (Giuliani and Bell 2005). Small regions with many less resourceful DUI-firms

may experience the most severe difficulties in obtaining extra-regional knowledge networks, which again points to problems in constructing regional advantage in small regions.

The above theoretical discussion points to the fact that the CRA-framework is better adapted to the situation in large than small regions. Large regions tend to have many STI-firms, narrow regional innovation systems with specialised knowledge organisations, related variety in the form of urbanisation economies and resourceful firms that can link up to external knowledge bases. From a conceptual point of view, small regions with weak RIS experience limitations with each of the four building blocks: comparatively few STI-firms, no or few specialised knowledge organisations, little related variety and relatively few resourceful firms in extra-regional knowledge networks. The paper next discusses how these theoretical assumptions stand up when subjected to empirical inspections in four regional industries in Norway.

Method

The investigation of the four cases is designed as theoretically informed case studies (Sayer 1992, Yin 2009), in which the empirical data material consists of a survey, informant interviews and former studies. The paper draws on results from studies of four regional industries, which have been selected to cover precisely the span of different innovation modes, from a typical STI to a typical DUI industry (cf. Table 1). The biotechnology industry in Tromsø is the classic example of an STI based industry, while the oil and gas equipment supplier industry traditionally follows the DUI mode of innovation. The two other industries fall somewhere between these examples.

The four regions have between 68,000 and 180,000 inhabitants (Table 1). These are small and medium sized regions in a Norwegian context, and are definitely small in international terms. Tromsø is dominated by service industries according to the 2008 update on the industrial structure in Norwegian municipalities by Statistics Norway (www4.ssb.no/stabas, see ‘classification of industrial link’). The service industries in Tromsø have more than twice the jobs in all other industries. The other regions are characterised by a mix of service industries and manufacturing industry, and have then a more diverse industrial structure. Raufoss is the most dominated by manufacturing industry, Agder the least.

Table 1 demonstrates that the selected industries, except for marine biotechnology, are quantitatively dominant within the manufacturing industries in their regions. Marine biotechnology has been a priority industry in Tromsø since the 1990s. Considerable resources have been invested to obtain a growing biotechnology industry, both through research activity at the University of Tromsø and policy tools to facilitate academic spin-offs, firm collaboration, etc. (Karlsen et al. 2011). Thus, the question of constructing regional advantage is highly relevant in the Tromsø case as in the three other cases including dominant regional industries.

The selected regional industries include different main types of firms (Table 1). The marine biotechnology industry in Tromsø includes two medium-sized firms in addition to very small firms, many of which are still in the product development phase. The three other regional industries are quite mature and include a regional production system in which most of the supply chains are found locally. The Horten and Raufoss firms often produce large

batches, while Agder firms most often produce one-off products or in small batches. The last three regional industries have a high export rate.

Table 1: Background information on the four cases compared

Regionⁱ	Tromsø	Horten	Raufoss	Agder
Number of inhabitants, 2010	80,000	115,000	68,000	180,000
Regional industry studied	Marine biotechnology	Electronics industry	Lightweight material production	Oil and gas equipment supplier industry
Number of jobs, 2009	160	2,500	4,000	6,000
Number of firms	11	35	50	45
Main types of firms	Mostly new and small firms, several in the product development phase	System firms and technology suppliers, often producing in large batches, and contract suppliers	Large, mass producing firms, smaller niche firms, machine builders and component suppliers	System firms with one-off products or small batches, component suppliers and engineering firms
Number of total manufacturing jobs, 2007	2,100	7,600	5,500	12,500
Main regional knowledge organisations	University of Tromsø, Norwegian Institute of Fisheries and Aquaculture	Vestfold University College	SINTEF Raufoss Manufacturing, Gjøvik University College	University of Agder

Source: Statistics Norway and own case studies

The analyses of the four cases builds on a number of previous theoretically informed case studies. The most recent of these were carried out from 2008 to 2010. The data material includes in all cases a web based survey for firm leaders, and also, in three of the cases, informant interviews with firms leaders and senior managers. One of the authors of the paper studied the fourth case (Horten), including informant interviews, in 2005, as reported in Isaksen (2007).

In fact, the web survey includes two surveys with different questionnaires which, to some extent, overlap. Both surveys focused on how firms perform innovation activity and the key internal and external knowledge sources in firms' innovation processes. Thus, the key information from the two surveys used in this paper is comparable. The analyses also build on information from other available material and informant interviews. The informants are general managers of smaller firms and technical directors, R&D managers in larger firms. The informants come from the largest firms in each case and from the different types of firms (such as system firms and contract suppliers) (Table 1). However, we did not aim for a statistically representative distribution of informants on different types of firms, rather informants in firms that are quite central in innovation activities in each regional industry, i.e. 'information-rich informants'. Apart from the largest firms, informants were selected based on advice from key actors in the regions. The informant interviews aimed to obtain more

detailed knowledge about the firms' production and innovation activities and their external knowledge links (Table 2).

The former case studies are extensively analysed and reported, with regard to Tromsø in Karlsen et al. (2011), Horten in Isaksen (2007), Raufoss in Isaksen and Karlsen (2012b) and Agder in Isaksen and Karlsen (2012a and 2012c). The Tromsø and the Agder cases are also compared in terms of the role of the regional universities in Isaksen and Karlsen (2010a), while Raufoss and Horten are two of the cases analysed in Isaksen (2009). This paper compares for the first time the four cases using a common analytical lens.

Table 2: Data sources for case study analyses. Number of answers on web surveys and number of interviews

Region	Tromsø	Horten	Raufoss	Agder
Web survey 1, 2008	7		24	
Web survey 2, 2009		31	17	39
Informant interviews, 2008-2010	5		26	12

Case studies of regional advantage

Diverse innovation modes

The marine biotechnology firms in Tromsø share many characteristics in their innovation activity with what is seen as typical for the biotechnology industry (Gertler and Levitte 2005). It is a matter of carrying out research, and to some extent basic research that is performed by researchers holding a PhD, and it often takes long time from research to medical products are launched on the market. Therefore, many firms in Tromsø are in the research and test phase of the innovation process. The importance of research activity means that the marine biotechnology firms in Tromsø are classified as STI- or a mix of STI- and DUI-firms (Karlsen et al. 2011). The element of practical knowledge and the DUI mode include firms with health related product like omega 3. The largest biotechnology firm in Tromsø (Probio) started with packing and distributing omega 3 tablets, but has subsequently become more research based and developed adjoining products. Generally, the marine biotechnology firms in Tromsø collaborate in projects with researchers from several universities.

The system firms and technology suppliers (Table 1) in the electronics industry in Horten follow in many ways a CCI based innovation mode. These firms hold highly advanced, science based technological core competence and long experience in product development (Isaksen 2007). The competence has been developed through systematic internal R&D-activity, and in collaboration with external research organisations, most often the largest national research institutes and the Norwegian University of Science and Technology (NTNU). The firms have dedicated R&D departments with often long experience in the running of R&D and innovation projects.

Several firms in the lightweight material industry in Raufoss are less product innovative than those in our first two cases because they are suppliers to the global automotive industry, i.e. they do not have their own products. The Raufoss firms, however,

operate often as first tier suppliers with regard to product development in customer projects, and they also systematically develop their own technological base. The innovation process in many Raufoss firms also resembles the CCI mode of innovation as it involves systematic R&D activity in internal R&D departments and in cooperation with external research institutes, combined with experience based knowledge in the firms (Isaksen and Karlsen 2012b). The firms possess some highly specific knowledge about product development and mass production of articles in aluminium, brass and composite where they supplement the competence of the car producers. As the firms are mainly mass producers a vital skill also includes the design and running of the production process, which is important knowledge when developing a new product.

The oil and gas equipment supplier industry in Agder has traditionally run innovation activities quite different from the other regional industries. The core of innovation processes in the equipment supplier industries consists of solving demanding tasks for customers through trial and error, adapting and developing existing solutions and making new solutions work by building on former successful projects (Isaksen and Karlsen 2010b). This has involved frequent, incremental improvements. Each project, for example, the building of new drilling equipments, has often included some small changes compared with the existing model, based on new ideas by the engineers. Although this has led to steady improvements, it is also a rather costly way of innovating as it hampers the standardisation of components and the systematisation of knowledge upgrading and innovation activities in the firms. Some firms, mostly the large system firms, have recently taken up more systematic innovation activity by having employees dedicated to R&D and technological development, and by setting up specific innovation projects. This also facilitates cooperation with external knowledge organisations compared with a situation in which all innovation activities are integrated in the daily work in the firms. Some system firms thus move towards a more CCI based innovation mode, while the component suppliers continue their typical DUI based mode and mostly follow up enquiries from local customers.

Function of regional innovation system

We will now analyse the extent to which regional advantages exist in the four regional industries and the type of advantage that is present. We follow the theoretical framework of CRA outlined above to answer this question, i.e. we examine 1) the function of the regional innovation system, 2) to what extent related variety exists and 3) the firms' use of external knowledge networks. The basic findings provide support for the line of reasoning in the theoretical part of the paper, but with some modifications.

The marine biotechnology industry in Tromsø is part of a narrow regional innovation system. The University of Tromsø, and partly the research institute Nofima Marin, function as key knowledge hubs for the local marine biotechnology industry. Research activities at the university, some strategic actors and entrepreneurs and the support system are behind the marine biotechnology industry in Tromsø (Karlsen et al. 2011). In many ways, Tromsø represents the effort to construct a new industry from scratch.

The other cases are quite different, although general industrial policies from the 1950s until the 1980s were important for the development of these regional industries. Particularly essential were the policies to create a more high technology Norwegian manufacturing

industry, military and re-purchase contracts, policies to increase the automatisisation and efficiency of ships and the fishing fleet and policies to develop a Norwegian oil and gas and equipment supplier industry for the Norwegian Continental Shelf. Raufoss is a special case; the state owned Raufoss Ammunition Factory acted, until the mid-1990s, as one instrument in efforts to create new manufacturing industries in Norway. In the two other cases an important part of the story is how entrepreneurs have utilised market possibilities and favourable policy support, which have consequently spurred local growth in these regions and industries.

The importance of the national policy is very evident in the electronics industry in Horten, which also points to the fact that the region is not the most relevant geographical scale in analyses of innovation processes in this case. A key source of research based knowledge for the system firms and technology suppliers in Horten is to be found in the largest universities and technological research institutes in Norway. The core competence in the Horten firms is built through long-term cooperation in innovation projects with large, national R&D-organisations and through recruiting from the universities. This cooperation has historical roots as the pioneer firms of the electronics industry in Horten came out of research in some national research organisations and large, national R&D projects during the 1960s. The Horten electronics industry is not part of a 'pure' regional innovation system, but rather what Asheim and Isaksen (2002) describe as a regionalised national innovation system. The typical example of this type of innovation system is regional clusters of firms where the vital knowledge providers are found outside the region. In the Horten case, Vestfold University College (located in Horten) started bachelor and master degree programmes in Micro Electro-Mechanical Systems (MEMS) technology during the 2000s. Although the university college has been a partner with local firms in several research programmes, its role as a contract research partner is limited (Herstad and Brekke 2012). The firms are highly embedded in the national innovation system and in global knowledge networks, while the role of the regional university college is first of all as a higher education institution.

The picture is quite different at Raufoss, which represents a highly interesting case of a closely linked regional innovation network. The core of the function of this network is cooperation in innovation projects between Raufoss firms and the local research organisation SINTEF Raufoss Manufacturing (SRM). This organisation has about 75 employees and is majority-owned by the largest technological research institute in the Nordic countries, SINTEF in Trondheim (which is the applied research institute of the Norwegian University of Science and Technology). The large mass producing firms act as drivers for technological development in the Raufoss industry. The firms enter into close cooperation with SRM in innovation projects. SRM has similar types of projects for several local firms, which lead to the accumulation of specialised knowledge and experience in SRM and, consequently, to the sharing of experience and knowledge among local and other companies. Thus, SRM act as a common knowledge hub for many local firms, which share a similar technological base in material technology and automated and lean production methods, but do not compete as they have different products.

The oil and gas equipment supplier industry in Agder has actually become world leading in some product niches such as drilling systems, loading and anchoring equipments and offshore cranes almost without cooperation in innovation projects with universities or research institutes. A key in innovation processes in this industry is historically created

experience and skills in technological fields like hydraulics among engineers. Experience among producers rather than R&D activity is the traditional strength in Agder. The system firms with their own products collaborate with local component suppliers to build prototypes, and which hold extensive production capability.

Extent of related variety

The marine biotechnology industry in Tromsø represents an interesting case with regard to related variety. Karlsen et al. (2011) consider few firms, few jobs and hence following little critical mass as constituting a weak point in this industry. Obviously, this reflects the fact that the industry in Tromsø is fairly young and that it takes time to build a critical mass, in particular if the commercialisation phase lasts long. But the firms also exchange fairly little market based and technological information and knowledge (Karlsen et al. 2011). The firms have in general close links with the University of Tromsø but few knowledge links exist between the firms themselves. Few firms and little knowledge spillover result in small agglomeration economies, and those that may exist mostly include specialised localisation economies as the firms and the regional industry are much geared towards R&D activity and the STI innovation mode. The firms and the Tromsø region (which is dominated by service industries) have less experience based knowledge with regard to the installing and running of production lines and other knowledge to commercialise research results.

The specialised industries in Horten and Raufoss have some related variety. Notably, in both these cases, the system firms that produce complex products find many component suppliers and service firms locally. The system firms in Horten lost most of their production competence as nearly all production activities were outsourced, mainly to newly established local contract suppliers, during the 1980s (Isaksen 2007). These suppliers, for example, build prototypes, give feedback on the technical design of prototypes and test if products can be effectively produced. Likewise, the lightweight material industry at Raufoss includes considerable local collaboration and knowledge spillovers. Particularly pronounced is the way research based and practical, experience based knowledge about production processes are interwoven, both inside firms and through external cooperation which includes SRM. This points to some degree of related variety of innovation modes and knowledge bases within the Horten and Raufoss industries, but variety found within a somewhat narrow set of industrial sectors, materials and production techniques.

The Agder oil and gas equipment supplier industry may include some amount of related variety of the Horten and Raufoss type, but which is not really activated as a result of some barriers to knowledge exchange in this industry. We refer, more precisely, to how the relations between the large system firms and the local component suppliers in Agder are organised. The system firms have mainly used the suppliers as flexible producers of components and parts that are fully designed and specified by the system firms themselves. The production competence by suppliers, for example, in the consultancy and design of components that is more simple and economical to produce, is only scarcely used by the large system firms. Thus, little interactive learning goes on between system firms as customers and local suppliers. The suppliers have then lost an opportunity to develop competence in larger parts of the value chain other than production, and with that also to compete on other parameters than mainly price for standardised production. This may mean that the potential

for linking of engineering based and practical, production based skills is not really exploited in this case.

Extra-region knowledge links

In all the cases, the firms, and particularly firms with their own products and technology, have many types of extra-regional links. The various surveys reveal that first of all direct contact with customers and users, and requirements from these, are the most important information source for the firms' innovation processes. The firms in Tromsø, Horten and Raufoss also collaborate in innovation projects with external knowledge organisations, most often national organisations but also foreign ones. These include corporate R&D centres, especially in the case of Horten, and customers' R&D department, which is especially the case for automotive suppliers in Raufoss. The equipment suppliers in Agder, on the other hand, have traditionally few links to knowledge organisations.

Firms in three of the regional industries are integrated in global production and knowledge networks first of all through external ownerships. We denote these as knowledge links insofar as a number of firms in the surveys report that sister firms and corporate departments are important information sources in innovation processes and important innovation partners. One half to three quarters of the firms in Horten, Raufoss and Agder are part of larger corporations headquartered elsewhere, while firms in Tromsø mostly have local owners. The externally owned firms include the largest and most advanced firms in Horten, Raufoss and Agder. These firms have in general a rather independent position within their corporations with regard to strategy, innovation activity and production. The independent position reflects that the firms often have competence not found in the rest of the corporations. The competence is linked to historically developed experience and knowledge inside the firms and in collaboration with national research organisations in the case of Horten and Raufoss. The competence is embedded in employees' experience and knowledge, as well as routines and established ways of doing things.

Conclusion: A recast CRA framework

In the examination of the CRA framework, the paper focused on two less considered questions ;

How and to what extent can small regions construct regional advantage? and

What type of firms may in particular contribute to constructing regional advantage in small regions?

The four different cases show diversities in existing regional advantages. The most important advantage in marine biotechnology in Tromsø is the research activity at the University of Tromsø, as well as the rest of the local research environment which has "produced" some knowledgeable entrepreneurs. Firm-specific R&D competence also represents a vital advantage in the Horten electronics industry. The competence is to a great extent acquired as a result of key persons benefitting from cross-project learning by remaining for a long time with the firms. However, the competence also makes up a regional specific advantage through the local labour market and knowledge spillovers. The possibility of linking such R&D based knowledge with practical knowledge in industrialisation at local suppliers and service firms also constitutes a vital advantage in this case. The same applies for

the lightweight material industry at Raufoss, which owes its main regional advantage to the combination of research activities in material technology, simulation, testing etc., and the historically developed, experience based knowledge in efficient mass production of lightweight products. The combination of knowledge bases has resulted in a unique competence in the Raufoss industry, which makes possible mass production of components for the cost cutting automotive industry in such a high cost location as Norway. A main advantage of the equipment supplier industry in Agder is the experience based production skills, with the capabilities to make new and complex products work.

The lesson from the empirical cases points to the fact that the CRA framework also represents a useful conceptual construct for studying industrial competitiveness in small regions with weak RIS. We propose, however, a number of reformulations to adapt more effectively the CRA framework to the characteristics of small regions. Our first suggestion is greater focus on the innovation capability of firms. The CRA framework deals with the knowledge bases and innovation modes of firms and clusters but does not really address the firm level. The empirical cases point to the importance of having some resourceful firms that can act as ‘door openers’ for other local firms to external knowledge. The development towards a more CCI based innovation mode in firms in the Agder equipment supplier industry illustrates this point. Firms can then upgrade their internal R&D capacity and more easily link up to knowledge organisations. The building of R&D and innovation capacity and capability inside firms is a relevant point in the CRA framework when employed in small regions.

A second reformulation includes placing less emphasis on the endogenous development capacity of regional innovation systems. The region is often not the most relevant geographical scale, and, consequently, RIS is not a key concept in analyses of innovation processes in small regions. The firms of Horten and Raufoss belong to strong national innovation systems, and a strong national policy of industrial development lies behind these – as well as the Agder – cases, which demonstrate advantages can be constructed without any functioning RIS, at least in the narrow definition of the concept. The CRA framework maintains that ‘the rationale for policy intervention is the reduction of interaction or connectivity deficits which lies at the core of a regional innovation system approach’ (EC 2006: 2), in other words to establish more cooperation with neighbouring firms and knowledge organisations. This is less relevant for small regions with weak RIS which have, in particular, few neighbouring knowledge organisations to cooperate with. Innovation systems as such are important for innovation processes in small regions, but the CRA framework should focus less on the need of regional presence of knowledge actors.

A third point concerns focusing more on experience based knowledge in local labour markets, which to some extent means underlining the importance of the broad rather than the narrow definition of RIS in small regions. Three of the cases (Horten, Raufoss and Agder) benefit much from unique, historically developed production competence. Many marine biotechnology firms in Tromsø, on the other hand, seem to have a too one-sided focus on science based knowledge and the STI innovation mode and suffer from a lack of experience based knowledge of production processes.

Fourth, related variety understood as spillover of complementary knowledge between firms through labour market dynamics, local collaboration and entrepreneurship is less relevant in small regions. This is due to the fact that small regions often have a thin or

specialised industrial structure, i.e. they lack the urbanisation economies of larger cities. Related variety is thus more adapted to analyses of large than small regions. We found, however, that a mix of knowledge bases and innovation modes in the regions is important for triggering innovation processes. This is illustrated by the Tromsø and Agder cases where little relevant experience based (Tromsø) and science based (Agder) knowledge are seen to hamper parts of firms' innovation activity. We see a need to focus more on the diversity of knowledge bases and on how to acquire relevant knowledge for innovation activity in small regions.

The empirical cases also point at some possible general policy lessons for constructing regional advantage in small regions. We propose that small regions should focus on the upgrading of their DUI-firms (while larger regions have more possibilities to upgrade existing, and to stimulate the formation of new, STI-firms). The opportunities to construct regional advantage lie in small regions (as in other regions) in capitalising on regions-specific assets (Asheim et al. 2011). Our theoretical discussion and empirical examples indicate that small regions have comparatively large experience based and context dependent knowledge in their DUI-firms and in local labour markets. This is mainly 'sticky' knowledge which is difficult to transfer from the regions, as opposed to much of the codified knowledge more often found in STI-firms and knowledge organisations (cf. Nuur and Laestadius (2010) on peripheral regions). While this is an asset, DUI-firms, and regions dominated by DUI-firms, need to upgrade their knowledge base and innovation capability. This can in principle occur by recruiting human capital to regional firms or organisations with related (and more science based) competence to the existing ones, by attracting firms or organisations to the region or stimulating the start-up of new firms and organisations with related knowledge, and by promoting collaboration with extra-regional actors.

Our results also indicate that extra-regional links are especially important in small regions. The research based knowledge of importance for firms in Horten and Raufoss is largely developed in collaboration with the largest Norwegian research institutes and universities. This is definitely the case in Horten, while Raufoss has a very important, locally placed research institute, which, nevertheless, is majority-owned by SINTEF in Trondheim, by far the largest technological research organisation in Norway. This implies that research based firms that require access to advanced, science based knowledge, at least in a small country like Norway, have to be supported by a national innovation system. Research based knowledge is often so specialised that the regional research capabilities of small regions often have little to contribute in support to STI and CCI-firms.

While the empirical focus in this paper has been upon four smaller Norwegian regions, it raises a broader question about how and the extent to which different regions can construct regional advantages. The conceptual construct of CRA is mostly built upon experiences of large city regions. There is a need for more theoretically informed studies of other types of regions, both smaller regions as in this paper, peripheral regions with a thin industrial structure, and old industrial regions. Such studies can supplement our attempt to reformulate the CRA framework to make it better adapted to differing regional circumstances.

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Notes

ⁱ The regions include here labour market regions (as defined by Statistics Norway, 1999), namely Tromsø, Tønsberg/Horten, Gjøvik (which includes the Raufoss cluster), and Kristiansand and Arendal (where the bulk of the Agder equipment supplier industry is found).