Environmental Innovations and Green skills in the Nordic countries

Østergaard, Christian Richter; Holm, Jacob Rubæk; Iversen, Eric; Schubert, Torben; Skålholt, Asgeir; Sotarauta, Markku

Published in:
Rethinking Clusters: Place-based Value Creation in Sustainability Transitions

DOI (link to publication from Publisher):
10.1007/978-3-030-61923-7

Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

Environmental innovations and Green skills in the Nordic countries

Christian Richter Østergaard (corresponding author)

Aalborg University Business School

Fibigerstræde 11, 9220 Aalborg, Denmark

cro@business.aau.dk

Jacob Rubæk Holm

Aalborg University Business School,Denmark

Eric Iversen

Nordic Institute for Studies in Innovation, Research and Education, Norway

Torben Schubert

Centre for Innovation, Research and Competence in the Learning Economy, Lund University, Sweden & Fraunhofer Institute for Systems and Innovation Research, Germany

Asgeir Skålholt

Nordic Institute for Studies in Innovation, Research and Education, Norway

Markku Sotarauta

Faculty of Management and Business, Tampere University, Finland

Abstract: In this chapter, we argue that policy-making aiming to achieve environmentally sustainable transitions of the economy are in need of a solid empirical evidence base. Conventional measurement concepts used for example by the EU based on sector-classifications deliver highly biased pictures. We propose measurement concepts based on the use of green skills and human capital, validate key assumptions of our concept and apply the concept to the four Nordic countries Denmark, Finland, Norway and Sweden. Our results show that indeed various versions of indicators based on green skills help predicting whether firms introduce environmental innovations, and this finding is robust across the four countries. Upon applying our measurement concept at the regional level, we find that the different Nordic countries show rather distinct patterns in their geographical distributions of these green skills, which may have implications for firms' capabilities to introduce environmental innovations.

Please cite this chapter as:
Østergaard C.R., Holm J.R., Iversen E., Schubert T., Skålholt A., Sotarauta M. (2021) Environmental Innovations and Green Skills in the Nordic Countries. In: Sedita S.R., Blasi S. (eds) Rethinking Clusters. Sustainable Development Goals Series. Springer, Cham. https://doi.org/10.1007/978-3-030-61923-7_14

Introduction[1]

Alongside the European Union, also the Nordic countries have adopted the Sustainable Development Goals (SDG) by the United Nations as part of their key policy missions. Several of these goals refer to the environmentally responsive production and consumption preserving natural resources and reducing negative environmental impacts (see in particular SDG 12-15). Achieving these goals will require a fundamental transition of economies reconciling environmentally sustainable practices with economic welfare considerations, which is typically achievable only through the implementation of improved technologies with lower environmental impact - thus, through what has been labelled green or environmental innovations (De Marchi 2012; Horbach and Rennings 2013; Rexhäuser and Rammer 2014). This reconciliation of conflicting goals puts high demands on policy-makers, who in turn are in great need of reliable empirical evidence-bases quantifying the grade of goal achievements of the SDGs.

[1] This chapter is based on a report by Østergaard et al. (2019). It is a part of the Geography of Nordic Sustainability Transitions (GONST) project funded by the Nordic Green Growth Research and Innovation Programme in cooperation with NordForsk, Nordic Innovation, and Nordic Energy Research (grant no. 83130).

As a matter of fact, policies aiming at the transition have unfortunately suffered from measurement challenges, which originate from dubious measurement concepts focusing on economic sectors as well as problems in data availability. The objective of this chapter is to describe weaknesses of existing sector-based measurement concepts such as the Environmental goods and services sector (EGSS) by the EU and propose focusing on the use of skills as inputs to sustainable transitions. Following Consoli et al. (2016), we argue that sustainable transitions building on environmental innovations require specific kinds of skills and human capital. Thus, instead of declaring ex-ante certain sectors as green, we argue that once we have identified the relevant skill sets, we have a basis for measuring sustainable transitions by measuring changes in the use of skills relevant for environmental innovations. We argue that our focus on skills counters many of the critiques of the sector-based approach. In particular, focusing on sectors ignores the fact that green transitions may occur in sectors that are not usually associated with being green (Shapira et al. 2014). Furthermore, sectors that produce goods and services that allow the users to become green, might not be green themselves. We thus avoid making ex-ante judgments of which sectors are green and which are not. Moreover, our approach allows measuring changes flexibly as they occur. Some sectors may not have been green in the past, but through environmental innovations may become so in the in the future. To the degree that such processes are reflected in changes in the skill bases, we will be able to identify the changes in the patterns flexibly without the need to adapt sectoral definitions continuously.

The purpose of this chapter is to identify green skills and analyze whether these skills are important for firms' introducing environmental innovations in the Nordic countries and then to show the use of these skills by regions in the Nordics. The paper therefore has one validation goal showing the principal adequacy of green skills to predict environmental innovations. It has also a descriptive goal by showing how the Nordic regions differ in their use of green skills. In that respect, rather than having an analytical contribution, this paper makes an exploratory methodological contribution to indicator-development in the field.

We draw on a combination of firm-level survey data on environmental innovations from the Community Innovation Surveys from 2014 (CIS) linked employee data on skills from Denmark, Sweden, Finland, and Norway to create detailed linked employer-employee datasets. The chapter develops education-based and occupation-based indicators for green skills and compare them to other definitions. The result is five different definitions of green skills, of which two are based on an individual's occupation, two on an individual's education, and one on is the classical sector based EGSS-classification. The occupation-based measures of green skills account for the largest share of green skills in the four Nordic countries, while the education based definitions account for the smallest. The results show that the green skill indicators are positively related to firms' likelihood of introducing environmental innovations. The education-based definition of green skills is particularly positive and statistically significant for the likelihood of introducing environmental innovation across the four countries. This is a strong indication of the importance of green skills. The different Nordic countries show rather distinct patterns in their geographical distributions of these green skills, which may have implications for firms' capabilities to introduce environmental innovations.

The role of green skills and the green economy

Greening of the economy and creating green growth is high on the policy agenda. OECD defines green growth as "fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies"[2]. In a rather similar way UNEP defines the green economy "as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011, p.2). Thus, compared to a 'brown economy' that does not address resource depletion, UNEP (2011) argues that a green economy should "reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services" (UNEP 2011, p.2).

Subsequently, a growing academic and non-academic literature is trying to identify the "green economy" by specific sectors, such as waste management and recycling or specific industries that have a high share of firms that supplies green goods and services. Furthermore, this has led to a discussion of greening of the economy in green, brown, white or even multicolored regions (Grillitsch and Hansen 2019). However, Shapira et al. (2014) argues that identifying green industries and green firms by using a set of pre-selected and designated industry classifications is conceptually problematic. Based on text mining and search term combinations on company databases and web pages, Shapira et al. (2014) show that green firms can be found in many 'non-green' industries. Thus, it is necessary to look at the broader greening of firms' activities regardless if these do not initially belong to green sectors.

While de-growth positions posit that green economies are only possible by zero or even negative growth strategies (Lorek and Spangenberg 2014; Hickel and Kallis 2020), the green growth view highlights the importance of environmental innovations (Jänicke 2012). While in this paper we do not intend to side with any of the views, it is clear that environmental innovations are an important building block in the greening of the economy even if natural resource constraints and continuous growth were not compatible in the long-run. Environmental innovations are usually defined as innovation with environmental benefits within the firm or for users or both (Community Innovation Survey 2014). This definition does not restrict the environmental innovations to specific industries and does not presume that the envi-

2 Definition found at www.oecd.org/greengrowth/ (checked May 13, 2020)

ronmental benefits were the main objective of the innovation or that the firms' activities are environmental friendly on the outset. These innovations require a novel way of utilizing existing knowledge or the creation of new knowledge to mitigate negative environmental impacts. A series of recent studies argues that firms' capabilities play an important role in creating environmental innovations (see e.g. Kesidou and Demirel 2012; Ketata et al. 2015). In general, developing environmental innovations is considered a more difficult task compared to traditional types of innovations, since firms need to also assess the environmental impact in the development process (Hall and Vredenburg 2003). In addition, a recent study of green patents shows that these inventions are more complex and more novel than other inventions (Barbieri et al. 2020). Therefore, environmental-innovative firms are often characterized by a higher R&D spending, a higher share of highly educated employees, and a more frequent rate of collaboration compared to non-environmental-innovative firms (Horbach 2008; De Marchi 2012; Cainelli et al. 2015; Christensen et al. 2019). Employees are the most important source for firms' innovation (Lundvall 2016). They are key contributors in an interactive innovation process, since knowledge and learning are basically resulting from employees' activities (Grant 1996; Lundvall 2016). A firm's employees account for its absorptive capacity, i.e. the ability to exploit external knowledge as well as the ability for firms to use internal knowledge (Cohen and Levinthal 1990).

Knowledge and skills of employees are not only seen as important for creating environmental innovations. There has been also a considerable effort to identify the extent of green skills available to support the growth of the green economy (see e.g. Cedefop 2019). The greening of the economy creates new green occupations and a greening of existing occupations, but also destroys occupations. However, in a study of skills for green jobs in six European countries, Cedefop (2019) finds that there is no common applied definition of green skills and jobs in the different countries, which makes it difficult to quantify their development and devise policies across countries. The report by Cedefop ironically concludes that green skills are defined often almost tautologically in these sense that they are defined as those skills applied in sectors or firms that are considered to be green.

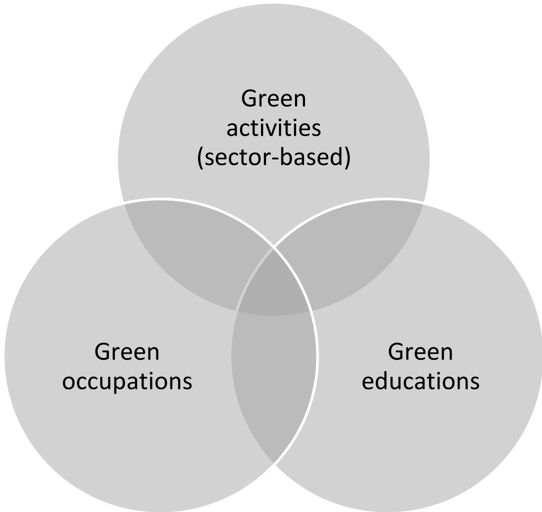
Several organizations have provided definitions of green skills and green jobs. The European Centre for the development of Vocational Training defines green skills as "the knowledge, abilities, values and attitudes needed to live in, develop and support a society which reduces the impact of human activity on the environment"(Cedefop 2012 p. 20). The U.S. Bureau of Labor Statistics defines green jobs as either: "Jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources or jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources". The International Labour Organization (ILO) defines green jobs as: "they reduce the consumption of energy and raw materials, limit greenhouse gas emissions, minimize waste and pollution, protect and restore ecosystems and enable enterprises and communities to adapt to climate change" (ILO 2018,p. 53), while skills are "defined as the ability to carry out the tasks and duties of a given job" (ILO 2012, p. 11). Furthermore, the ILO defines an occupation as "a set of jobs whose main task and duties are characterized by a high degree of similarity" (ILO 2012, p. 11). The ILO (2012) also uses the skill level and skill specialization to arrange occupations into groups. The skill level is a function of the complexity and range of the tasks and duties involved and the specialization is defined by "the field of knowledge required, the tools and machinery used, the materials worked on or with, as well as the kinds of goods and services produced" (ILO 2012, p. 11).

One of the difficulties in identifying green skills is that skills depend on the match between employees, knowledge and abilities and the task content of their work (Autor et al. 2003). Nelson and Winter (1982) define skills as: "a capability for a smooth sequence of coordinated behavior that is ordinarily effective relative to its objectives, given the context in which it normally occurs" (Nelson and Winter, 1982 p. 73). Skills are based on both codified knowledge about how to do a task in terms of a sequence of steps as well as a tacit knowledge in terms of making choices and doing a skillful performance of the tasks (Nelson and Winter, 1982). Thus, skills rely on know-how that is difficult to document, and which cannot be easily transferred between organizations and can only be learned through trial-and-error (Lundvall, 2016).

An influential study by Consoli et al. (2016) have identified the characteristics of green versus non-green jobs in terms of human capital and skills in the US. Based on detailed Occupational Information Network (O*net) occupational data they find that jobs that are becoming greener are characterized by a higher education, requiring more extended work experience and increased on-the-job training compared to non-green jobs (Consoli et al. 2016). Based on the work by Dierdorff et al. (2009), they identify 111 out of 905 occupations as green and estimate that 9 to 11 percent of all US jobs require green skills. Furthermore, occupations within management, architecture, and engineering have the largest share of green jobs.

Summing up, skills depend on several different factors such as formal education, work experience, and on-the-job training. This makes it difficult to identify green skills, since match between tasks, education, and experience is likely to change during the green transition of existing task or the emergence of new tasks. That is, some non-green skills can become green when they are reapplied or redirected towards new green objectives as well as related activities. Three different approaches can be identified: activity based, occupation based and education based. These are likely to differ, since the greening of the economy is taking place in most sectors, but there may also overlap, see Figure 1. However, there has not been so far any comparable analysis of these different definitions of green skills.

Fig. 1. The three definitions of Green skills



Methodology

In this chapter, we use several alternative methods for identifying green skills based on green activities, green occupations and green educations. These green skills are then compared using a regression analysis to study the co-occurrence of green skills and environmental innovation. Observing this co-occurrence will increase the validity of the measure of green skills and constitutes a basis for further work on the antecedents of environmental innovation.

The analysis is based on detailed matched employer-employee data from the four Nordic countries, Denmark, Norway, Finland and Sweden. The four countries differ in size, geography, industrial structure and technological specialization. Sweden is the largest country with 10.2 million inhabitants, followed by Denmark (5.8 million), Finland (5.5 million) and Norway (5.3 million). In the 2019 innovation scoreboard, Sweden, Finland and Denmark are labelled as innovation leaders, while Norway is a strong innovator. Sweden has a very high R&D spending of 3.4% of GDP per capita, Denmark 3.05%, Finland 2.76 %, and Norway 2.09%. All the countries have a large emphasis on greening of the economies, but using different methods and from different starting points relative to resources and industrial structure. Norway and to a lesser extent Denmark are oil producing countries. Sweden and Finland have a large share of the electricity production by nuclear power, which is banned in Norway and Denmark. Norway, Sweden and Finland all have large shares of electricity generation by hydropower, while Denmark has the largest share of electricity generated by wind power. These differences relate to differences in geography and in energy policy and is also likely to affect the extent of green skills in the countries. Tanner et al. (2019) analyses regional distribution of green patents in Denmark, Finland, Norway and Sweden. They show that the number and share of green patents have grown considerable since 2000 and find that all four countries have a higher share of green patents compared to the world average. The four countries are all specialized in energy technology, but with some differences. Denmark has a strong specialization in energy technology stemming from its wind turbine industry, while Finland is specialized in building technology and Sweden in transportation technology.

The data used in this chapter is matched employer-employee data as well as innovation survey data. The register-based data is reasonably similar and comparable in the four countries[3]. For Denmark, we used the Integrated Database for Labor Market Research (IDA). IDA contains detailed information on all firms, plants, and individuals that are active in the Danish labor market. The database also contains detailed information on people's educations and occupations. For Sweden, we used the Swedish linked employer-employee database (LISA), and the company-register database, which contains detailed information on all firms, plants and individuals, which are active on the Swedish labor market. For Finland, we used the Finnish Longitudinal Employer-Employee Data (FLEED) and the company-register database is used. FLEED contains detailed information on firms, plants and individuals. For Norway, we used the Norwegian linked employer-employee database, consisting of official employment data matched with the official registry of companies registered in Norway. This core-data provides full count of employees and employers in Norway.

For Denmark, Sweden, and Finland, the innovation output–based approach was taken from the Community Innovation Survey (CIS) 2014. This survey included a voluntary module on innovations with benefits for the environment. In the survey, firms indicate whether they had introduced innovations with one or more environmental benefits in the period 2012–2014. The benefits could be for the firm itself or produced during the use of the product or service by the end-user. The survey contains information on a stratified sample of firms for each country, which are selected based on size, industry affiliation, and R&D intensity. This module was not included in the Norwegian CIS. However, the Norwegian Survey on Research and Development and Innovation asks Norwegian firms the extent to which the reduction of environmental impacts was important when developing new products or processes. We were therefore able to identify environmental innovators in 2014 in all countries and match these to the employer-employee databases.

Regions are defined at the NUTS 3 level (Nomenclature of Territorial Units for Statistics), despite they differ greatly in geographical size between the countries. Industries are based on Eurostat's definition of industries according to the technological intensity of their manufacturing and services.

---

3 See Østergaard et al. (2019) for more detailed information on databases and innovation survey.

To analyze the relation between green skills and environmental innovations, we run a series of logistic regression models for the likelihood of introducing environmental innovations. The models apply the different indicators for green skills. The controls are: share of highly educated employees, firm size (logarithm), region, and industry. The models are run for each country separately.

Approaches to identifying green skills

Three different approaches were used to identify green skills, as seen in Figure 1. The first approach focuses on the activities of the firm at which a person works. If a person works at a firm that performs a green activity, then the person has green skills. The second approach defines an individual as having green skills if his/her education is classified as green. Finally, the third approach focuses on the tasks performed in the job by the individual. If the job's occupation code is classified as green, then the individual has green skills.

Green activities

The activity-based definition of green skills is based on Eurostat's definition of the environmental goods and services (EGSS) industry (Eurostat 2016). The green industries are defined as a narrow selection of industries that are closely related to recycling and environmental protection. Obviously, this is a very simple definition that only covers a small share of employees and firms potentially involved in environmental innovation. These are (NACE codes Rev. 2, 4-digit level): 2211 Manufacture of rubber tires and tubes; retreading and rebuilding; 3700 Sewerage; 3811 Collection of nonhazardous waste; 3812 Collection of hazardous waste; 3821 Treatment and disposal of nonhazardous waste; 3822 Treatment and disposal of hazardous waste; 3831 Dismantling of wrecks; 3832 Recovery of sorted materials; 3900 Remediation activities and other waste management services.

Green educations

Two education-based definitions were used to identify green skills. One definition is based on International Standard Classification of Education (ISCED), while the other is based on national educational codes. For both definitions, we only considered education at a level corresponding to a vocational bachelor (level 5 in the European Qualification Framework) or higher.

Using a text-based analysis using the following search strings: "environ," "energy," "waste," "recycle," "wind," "sustain" and "solar.", the *green* indicator is based on four ISCED 2013F fields of education: 0521 (environmental sciences), 0522 (natural environments and wildlife), 0712 (environmental protection technology), and 0713 (electricity and energy) (UNESCO 2015). The national definitions are also based on a textual analysis using similar and additional search terms (see Østergaard et al. 2019 for the detailed country specific searches).

Green occupations

The occupation-based approach resulted in two definitions. The first definition of green occupations is based on a translation of the definition of green skills in Vona et al. (2015) and Consoli et al. (206). They investigated which vocations that corresponded with green tasks using O*NET, a US occupational information network. We will make use of occupations with a "greenness" above 1 in Vona et al.'s 2015 work (p. 43). The approach is also similar to that used by Yi (2013).

These green occupations were translated from the American Standard Occupational Classification (SOC) from 2010 into the International Labour Organization's (ILO) International Standard Classification of Occupations (ISCO).[4] The ISCO code is not as nuanced as the 2010 SOC. However, in Norway, Denmark, and other countries, more detailed occupational codes exist that enabled us to come closer to the definition in Vona et al. (2015). The results of a direct application of the crosswalk between SOC and ISCO are presented in the appendix. This approach can lead to categories that appear rather broad.

The second definition labelled *green GONST* is based on a text-based analysis of the ISCO-08 detailed descriptions of tasks related to occupations using the following search strings: "environ," "energy," "waste," "recycle," "wind," and "solar."[5] This definition appears to be narrower and more precise in capturing green occupations. The detailed definition can be seen in the appendix[6].

Results

This chapters' main goal is to investigate if our different approaches to identify green skills matter. We do this by running logistic regressions on the outcome of the firm being an environmental innovator, controlling for important company demographics and our measurements of green skills (Table1).[7]

---

4 Crosswalk developed by the Bureau of Labor Statistics: https://www.bls.gov/soc/soccrosswalks.htm

5 The ILO's international standard classification of occupations: http://www.ilo.org/public/english/bureau/stat/isco/and http://www.ilo.org/public/english/bureau/stat/isco/docs/groupdefn08.pdf

6 There are some differences between the uses of ISCO definitions in the different countries. See Østergaard et al. (2019) for the details of differences.

7 A firm is defined as having green skills if the firm has at least one employee with green education, green occupation and so on.

Table 1 Regressions for environmental innovation

	Green occupation				Green occupations GONST			
	Norway	Denmark	Sweden	Finland	Norway	Denmark	Sweden	Finland
Green occupation	0.387***	0.237	0.360***	0.074				
	(0.148)	(0.234)	(0.034)					
Green occupation GONST					0.666***	0.239	0.247***	0.557
					(0.147)	(0.368)	(0.041)	
Share of high ed. empl.	0.004**	-0.389***	0.235***	-0.026	0.004***	-0.380***	0.150*	-0.027
	(0.002)	(0.134)	(0.074)	(0.002)	(0.113)	(0.077)		
Log(size comp)	0.229***	0.237***	0.0003***	1.127***	0.251***	0.235***	0.0003***	1.127***
	(0.028)	(0.024)	(0.000)	(0.026)	(0.024)	(0.000)		
Regions	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES
Intercept	-2.600***	-1.403***	-0.758***	1.941**	-2.598***	-1.383***	-0.689***	-1.888*
	(0.250)	(0.233)	(0.043)	(0.250)	(0.233)	(0.042)		
Pseudo R2	0.063	0.317	0.057	0.156	0.061	0.317	0.049	0.156
N	5250	1739	7722	2326	5250	1739	7722	2326

Standard errors in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01

We had two different measurements based on vocational codes. We see that both measures are significant positively related to the firm's likelihood of being an environmental innovator in Norway and Sweden. We see that the relationship is also positive for Finland and Denmark, but not significant.

When it comes to our measurement of green education, and the activity-based measurement of being in a green industry (EGSS), we find the following results, see Table 2.

Table 2 Regressions for environmental innovation

	Green education				EGSS			
	Norway	Denmark	Sweden	Finland	Norway	Denmark	Sweden	Finland
Green education	0.562***	3.617***	0.175***	1.113*				
	(0.118)	(0.744)	(0.061)					
EGGS					1.353***	1.108**	0.066	-0.155
					(0.203)	(0.436)	(0.124)	
Share of high ed. empl.	0.003*	-0.493***	0.258***	-0.252*	0.005***	-0.371***	0.287***	0.024
	(0.002)	(0.138)	(0.074)	(0.002)	(0.134)	(0.074)		
Log(size comp)	0.216***	0.239***	0.0003***	1.118***	0.278***	0.237***	0.0004***	1.126***
	(0.028)	(0.024)	(0.0000)	(0.026)	(0.024)	(0.0000)		
Regions	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES
Intercept	-2.473***	-1.402***	-0.676***	-1.877*	-2.721***	-1.411***	-0.714***	-1.724
	(0.253)	(0.233)	(0.042)	(0.251)	(0.233)	(0.041)		
Pseudo R2	0.0637	0.3251	0.046	0.158	0.0671	0.3196	0.045	0.156
N	5250	1739	7722	2326	5250	1739	7722	2326

Standard errors in parentheses
* p < 0.1, ** p < 0.05, *** p <0.01

There is a statistically significant and positive relationship between a firm having employees with green education and the firm's likelihood of being an environmental innovator in all four countries, see tables 1 and 2. The results are not so clear when it comes to EGSS. The EGSS relationship is significant and positive for Denmark and Norway, positive but not significant in Sweden and negative but not significant in Finland. The education-based definition of green skills is particularly positive and statistically significant for the likelihood of introducing environmental innovations across the four countries. The fact that this result was found for all four countries is a strong indication of the importance of green skills. Size is also positively related to introducing environmental innovations whereas the share of highly educated employees differs between the countries[8].

8 For the detailed regression results, see Østergaard et al. (2019)

Employees with green skills are important for introducing environmental innovations in all Nordic countries, but access to these skills might differ between and within countries. Table 3 shows the share and number of employees with green skills in Denmark according to the three approaches and the related five different definitions for the year 2014. The broad occupation-based definition (labeled *green* in the table) is the largest category with more than 95,500 employees, amounting to 3.65% of the total number of employees in Denmark. The more precise and narrower *green GONST* sums to 23,500, which is only 0.87 % of the total workforce. The education-based definitions resulted in fewer employees with green skills. The broad education-based definition *green* resulted in 8,382 jobs, while the narrower definition based on the Danish educational codes *green Denmark* only identified 2,881 jobs, or 0.11% of the total employment. The activity-based EGSS definition resulted in 9,430 jobs, which is equivalent to 0.36% of the total number of employees.

Table 1 Share (%) and number of employees with green skills in Denmark in 2014

		Share with green skills				
		Occupation-based	Education-based	Activity-based		
	Employment in 2014	Green	Green GONST	Green	Green Denmark	EGSS
Byen København	405,298	2.95	1.34	0.29	0.20	0.15
Københavns omegn	307,492	4.13	1.65	0.66	0.16	0.45
Nordsjælland	166,236	3.61	1.00	0.50	0.12	0.22
Bornholm	16,242	2.79	0.43	0.07	0.05	0.60
Østsjælland	93,008	3.03	0.75	0.20	0.15	0.45
Vest- og Sydsjælland	214,303	2.67	0.51	0.12	0.07	0.41
Fyn	200,974	3.67	0.48	0.13	0.04	0.59
Sydjylland	330,660	4.57	0.77	0.28	0.06	0.37
Vestjylland	204,209	4.70	0.47	0.32	0.06	0.38
Østjylland	387,278	3.69	0.86	0.40	0.06	0.36
Nordjylland	258,063	3.72	0.59	0.21	0.12	0.48
Not regionalized	35,864	0.17	0.03	0.06	0.06	0.00
Total	2,619,627	3.65	0.90	0.32	0.11	0.36

Table 4 shows the share and number of employees with green skills in Norway according to the five different definitions for the year 2014. The measures for green occupations indicate a band of between 7,700 (0.3%) and 134,600 employees (5.3%) working in Norway in green occupations in 2013. This range is admittedly broad. A comparison of the different measures, however, suggests that the number is probably closer to the floor of this band. The identification of green education suggests that 0.2% of the Norwegian workforce hold higher degrees in the green fields, while about 12,800 (0.5%) employees work in green firms (EGSS).

Table 4 Share (%) and number of employees with green skills in Norway in 2014

Share with green skills						
		Occupation-based	Education-based		Activity-based	
	Employment in 2013	Green	Green GONST	Green	Green Norway	EGSS
Østfold	116,528	4.6	0.3	0.1	0.1	0.7
Akershus	256,097	5.2	0.2	0.2	0.2	0.5
Oslo	441,822	4.1	0.1	0.2	0.2	0.3
Hedmark	84,791	4.2	0.4	0.2	0.2	0.6
Oppland	85,778	4.0	0.4	0.1	0.2	0.7
Buskerud	123,725	5.8	0.3	0.1	0.2	0.5
Vestfold	103,833	5.0	0.2	0.1	0.1	0.5
Telemark	75,048	5.2	0.4	0.3	0.3	0.7
Aust-Agder	48,089	4.6	0.4	0.1	0.2	0.5
Vest-Agder	86,638	7.1	0.3	0.1	0.1	0.5
Rogaland	243,425	7.8	0.3	0.1	0.1	0.5
Hordaland	254,691	6.3	0.2	0.1	0.1	0.4
Sogn og Fjordane	53,775	4.5	0.3	0.3	0.3	0.7
Møre og Romsdal	128,521	6.3	0.3	0.1	0.1	0.4
Sør-Trøndelag	159,591	4.7	0.2	0.2	0.3	0.4
Nord-Trøndelag	61,903	5.2	0.4	0.2	0.2	0.5
Nordland	114,558	4.6	0.4	0.1	0.1	0.5
Troms	81,695	4.0	0.3	0.1	0.1	0.5
Finnmark	37,116	4.5	0.5	0.2	0.3	0.6
Total	2,557,624	5.3	0.3	0.2	0.2	0.5

Table 5 presents the basic results from the three measures of green skills used for Sweden. As in the other countries, the broadest definition arises from green occupations based on the direct adaptation of Vona et al. (2015). According to this definition, 3.48% of all employees have a green occupation. If we use the narrower and more precise GONST definition of green occupations, the share of employees drops to 0.78%. Based on their educational background, we identified that the 0.17% of Swedish employees possesses green skills. In terms of the activity-based definitions, the overall share of employment is 0.48%, higher than the education-based definition but lower than any of the occupation-based definitions.

Table 5 Share (%) and number of employees with green skills in Sweden in 2014

Share with green skills						
		Occupation-based		Education-based		Activity-based
	Employment in 2014	Green	Green GONST	Green	Green Sweden	EGSS
Stockholm	1,187,586	2.98	0.66	0.15	NA	0.28
Uppsala	145,747	3.53	1.22	0.31	NA	0.62
Södermanland	102,301	2.79	0.54	0.20	NA	0.91
Östergötland	182,465	4.12	1.12	0.21	NA	2.46
Jönköping	166,225	3.82	0.53	0.12	NA	0.23
Kronoberg	106,231	3.67	0.32	0.14	NA	0.08
Kalmar	99,093	3.29	0.61	0.17	NA	0.24
Gotland	29,013	4.33	0.58	0.19	NA	0.03
Blekinge	53,909	3.03	0.59	0.16	NA	0.14
Skane	523,200	3.50	0.73	0.17	NA	0.50
Halland	127,009	3.61	0.85	0.16	NA	0.35
Västra Götaland	808,053	3.97	0.69	0.16	NA	0.55
Värmland	108,373	3.21	1.58	0.19	NA	0.43
Örebro	158,383	3.16	0.63	0.16	NA	0.25
Västmanland	127,239	3.66	0.61	0.15	NA	0.37
Dalarna	134,186	3.82	0.71	0.20	NA	0.25
Gävleborg	119,066	4.19	1.04	0.13	NA	0.62
Västernorrland	112,923	3.68	1.98	0.15	NA	1.34
Jämtland	66,403	2.04	0.71	0.30	NA	0.13

Västerbotten	118,378	2.99	1.15	0.33	NA	0.26
Norrbotten	117,803	4.50	0.94	0.17	NA	0.32
Total	4,593,586	3.48	0.78	0.17	NA	0.49

Table 6 shows the share and number of employees with green skills in Finland. Green occupation is the largest classification with more than 94,000 employees, which represents 4.3% of the total number of employees in Finland. The narrow definition of green occupations (*green GONST*) sums to 5,410 employees, which amounts to only 0.25% of the total number of employees. Differences between the shares of green occupations in the Finnish regions are minor. In absolute terms, the majority of people working in green occupations are located in the core regions of Finland: Uusimaa, Tampere Region, Southwest Finland, and Northern Ostrobothnia. In relative terms, Tampere Region, South Karelia, Satakunta, and Tavastia Proper have slightly more employees working in green occupations than the other regions.

Table 6 Share (%) and number of employees with green skills in Finland in 2014

Share with green skills						
		Occupation-based		Education-based		Activity-based
	Employment in 2014	Green	Green GONST	Green	Green Finland	EGSS
Uusimaa	714,814	4.33	0.23	2.92	NA	0.19
Varsinais-Suomi (Southwest Finland)	188,533	4.33	0.18	1.52	NA	0.29
Satakunta	85,179	4.69	0.31	1.69	NA	0.47
Kanta-Häme (Tavastia proper)	70,539	4.63	0.28	1.69	NA	0.46
Pirkanmaa (Tampere region)	198,396	4.89	0.20	3.34	NA	0.26
Päijät-Häme	75,252	4.34	0.24	1.89	NA	0.33
Kymenlaakso	65,279	4.37	0.25	2.34	NA	0.43
Etelä-Karjala (South Karelia)	49,416	4.74	0.18	2.49	NA	0.29
Etelä-Savo (Southern Savonia)	54,737	3.45	0.33	1.89	NA	0.25

Pohjois-Savo (Northern Savonia)	93,545	4.12	0.31	2.34	NA	0.26
Pohjois-Karjala (North Karelia)	58,814	3.98	0.40	1.32	NA	0.31
Keski-Suomi (Central Finland)	101,678	4.33	0.28	2.20	NA	0.27
Etelä-Pohjanmaa (South Ostrobothnia)	74,988	3.65	0.18	1.45	NA	0.27
Pohjanmaa (Ostrobothnia)	76,469	4.19	0.22	3.11	NA	0.30
Keski-Pohjanmaa (Central Ostrobothnia)	27,092	3.85	0.30	1.57	NA	0.39
Pohjois-Pohjanmaa (Northern Ostrobothnia)	150,704	4.22	0.26	2.58	NA	0.30
Kainuu	27,488	3.19	0.35	1.52	NA	0.31
Lappi (Lapland)	664,20	3.98	0.40	1.47	NA	0.33
Total	2,192,654	4.30	0.25	2.41	NA	0.28

Comparing the different definitions of green skills it can be seen that the broad occupation-based measure of green skills (labeled *green*) accounts for the largest share of green skills in the four Nordic countries ranging between 3.5%-5.3%. This is a considerably lower number than that found in Consoli et al. (2016), who argued that 9%–11% of all jobs in the US require green skills. However, these numbers are not directly comparable since Consoli et al. (2016) used a US-specific type of data that is not available in the Nordic countries. Arguably, Consoli et al.'s (2016) percentage seems very high. The BLS found that the 2.6% of total employment was associated with the production of green goods and services (Chadwick et al., 2013). The narrower occupation-based measure (labeled *green GONST*) only found that between 0.25%–0.90% of occupations require green skills. This definition appears to be narrower and more precise in capturing green occupations, but it obviously only accounts for a limited number of people. There are regional differences within the four countries, but there seems not to be any systematic differences and specialization patterns.

The education-based measures also only accounts for a low share of employees, ranging from 0.17% to 0.32%, except for Finland, where the 2.41% of employees has a green education). Finland is a country with many engineers, but there seems to be a difference in the registration of these compared to the other countries. It seems to be obvious that the measures used here are not perfect in capturing all green skills. However, employees with green skills are important if firms are going to introduce environmental innovations.

Conclusion

The purpose of this chapter was to identify green skills and analyze whether these skills are important for firms' introducing environmental innovations in Denmark, Norway, Sweden, and Finland. Identifying green skills proved to be rather difficult, since skills depend on several factors, such as education, experience, and on-the-job training as well as the match between these factors and the ability to carry out the task content of the job. We created five different indicators of green skills based on description of tasks related to an occupation, content in an education and activity of the firm. Two of these indicators were country specific education based indicators created for Norway and Denmark. These different indicators revealed a rather surprisingly low share of green skills in the Nordic countries that also were much lower than previous finding from the US. This highlights the difficulties in measuring green skills using register data.

An education provides people with knowledge, basic concepts, and models for problem solving (Brown and Duguid 2001), but the education can be applied to different tasks in different jobs. In addition, the content and tasks of existing jobs might also be changing over time. This is almost impossible to detect using register data or even using more or less detailed job descriptions. A change in focus or tasks of a job towards generating environmental benefits or reducing environmental harm is difficult to measure. Therefore, we are only able to find low shares of green skills in the Nordic countries using the different definitions. However, the regressions for likelihood of environmental innovation show that, the green skill indicators are positively related to firms' likelihood of introducing environmental innovations in all four countries. Especially the education based definition of green skills is positive and statistically significant for the likelihood of introducing environmental innovation across the four countries. This shows that although our indicators for green skills might not capture all employees with green skills, we are nevertheless able to find skills that are relevant for environmental innovation. This indicates that innovation policy including educational policy can play an active role in promoting green skills, environmental innovation and the sustainable transition of the economy. Lundvall (2016) argues that targeted innovation policies are needed to create green growth: "very ambitious combinations of education, life- long learning and labour market policies will be required in order to transform green innovations into wide production and use" (Lundvall 2016, p.388).

However, having employees with green skills is not a sufficient nor necessary condition in order for firms to introduce environmental innovations. Recent research show that these firms also are more collaborative in their innovation process and spend more on R&D and training of employees (Cainelli et al. 2015; Christensen et al. 2019). Therefore, future research should focus on the composition and skills of employees in environmental innovative firms.

References

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. *The Quarterly journal of economics*, *118*(4), 1279-1333. doi.org/10.1162/003355303322552801

Barbieri, N., Marzucchi, A., & Rizzo, U. (2020). Knowledge sources and impacts on subsequent inventions: Do green technologies differ from non-green ones?. *Research Policy*, *49*(2) doi.org/10.1016/j.respol.2019.103901

Brown, J. S., & Duguid, P. (2001). Knowledge and organization: A social-practice perspective. *Organization science*, *12*(2), 198-213. doi.org/10.1287/orsc.12.2.198.10116

Cainelli, G., De Marchi, V., & Grandinetti, R. (2015). Does the development of environmental innovation require different resources? Evidence from Spanish manufacturing firms. Journal of Cleaner Production, 94, 211-220. doi.org/10.1016/j.jclepro.2015.02.008

CEDEFOP. (2019). Skills for green jobs: 2018 update. European synthesis report. Luxembourg: Publications Office. Cedefop reference series; No 109.

CEDEFOP. (2012). Green Skills and Environmental Awareness in Vocational Education and Training Synthesis Report.

Chadwick, A. L., DeWolf, M., Fett, N. A., & Viegas, R. L. (2013). Green Goods and Services survey: results and collection. *Monthly Lab. Rev.*, *136*, 1.

Christensen, J. L., Hain, D. S., & Nogueira, L. A. (2019). Joining forces: collaboration patterns and performance of renewable energy innovators. Small Business Economics, 52(4), 793-814. doi.org/10.1007/s11187-017-9932-0

Cohen, W.M. & Levinthal, D.A. (1990). Absorptive capacity: a new perspective of learning and innovation. Administrative Science Quarterly 35 (1), 128–152.

Consoli, D., Marin, G., Marzucchi, A., & Vona, F. (2016). Do green jobs differ from non-green jobs in terms of skills and human capital?. Research Policy, 45(5), 1046-1060.

De Marchi, V. (2012). Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms. *Research policy*, *41*(3), 614-623. doi.org/10.1016/j.respol.2011.10.002

Dierdorff, E. C., Norton, J. J., Drewes, D. W., Kroustalis, C. M., Rivkin, D., & Lewis, P. (2009). Greening of the world of work: Implications for O* NET®-SOC and new and emerging occupations. *O* NET, February*

Eurostat. (2016) Environmental goods and services sector accounts. Luxembourg: Publications Office of the European Union.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic management journal*, *17*(S2), 109-122.

Grillitsch, M., & Hansen, T. (2019). Green industry development in different types of regions. *European Planning Studies*, *27*(11), 2163-2183. doi.org/10.1080/09654313.2019.1648385

Hall, J., & Vredenburg, H. (2003). The challenge of innovating for sustainable development. *MIT Sloan Management Review*, *45*(1), 61.

Hickel, J., & Kallis, G. (2020). Is green growth possible?. *New political economy*, *25*(4), 469-486. doi.org/10.1080/13563467.2019.1598964

Horbach, J. (2008). Determinants of environmental innovation—New evidence from German panel data sources. *Research policy*, *37*(1), 163-173. doi.org/10.1016/j.respol.2007.08.006

Horbach, J., & Rennings, K. (2013). Environmental innovation and employment dynamics in different technology fields–an analysis based on the German Community Innovation Survey 2009. *Journal of Cleaner Production*, *57*, 158-165. doi.org/10.1016/j.jclepro.2013.05.034

International Labour Office (ILO). (2018). World Employment and Social Outlook 2018: Greening with jobs.

International Labour Office. (2012). International Standard Classification of Occupations 2008 (ISCO-08): Structure, group definitions and correspondence tables. International Labour Office.

Jänicke, M. (2012). "Green growth": from a growing eco-industry to economic sustainability. *Energy Policy*, *48*, 13-21. doi.org/10.1016/j.enpol.2012.04.045
Kesidou, E., & Demirel, P. (2012). On the drivers of eco-innovations: Empirical evidence from the UK. *Research Policy*, *41*(5), 862-870. doi.org/10.1016/j.respol.2012.01.005
Ketata, I., Sofka, W., & Grimpe, C. (2015). The role of internal capabilities and firms' environment for sustainable innovation: evidence for Germany. *R&D Management*, *45*(1), 60-75.
Lorek, S., & Spangenberg, J. H. (2014). Sustainable consumption within a sustainable economy–beyond green growth and green economies. *Journal of cleaner production*, *63*, 33-44. doi.org/10.1016/j.jclepro.2013.08.045
Lundvall, B. Å. (2016). *The learning economy and the economics of hope* (p. 377). Anthem Press.
Nelson, Richard R., & Winter, G. Sidney (1982). *An evolutionary theory of economic change*
Østergaard, C. R., Holm, J. R., Iversen, E., Schubert, T., Skålholt, A., Sotarauta, M., Saarivirta,T. & Suvinen, N. (2019). The Geographic Distribution of Skills and Environmentally Innovative Firms in Denmark, Norway, Sweden, and Finland. *AAU, Department of Business and Management: Aalborg*.
Rexhäuser, S., & Rammer, C. (2014). Environmental innovations and firm profitability: unmasking the Porter hypothesis. *Environmental and Resource Economics*, *57*(1), 145-167.
Shapira, P., Gök, A., Klochikhin, E., & Sensier, M. (2014). Probing "green" industry enterprises in the UK: A new identification approach. Technological Forecasting and Social Change, 85, 93-104. doi.org/10.1007/s10640-013-9671-x
Tanner, A. N., Faria, L., Moro, M. A., Iversen, E., Østergaard, C. R., & Park, E. K. (2019). Regional distribution of green growth patents in four Nordic countries: Denmark, Finland, Norway and Sweden.
UNEP (2011). Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers
UNESCO (2015.) International Standard Classification of Education: Fields of Education and Training 2013 Detailed field descriptions
Vona, F., Marin, G., Consoli, D., & Popp, D. (2015). *Green skills* (No. w21116). National Bureau of Economic Research.
Yi, H. (2013). Clean energy policies and green jobs: An evaluation of green jobs in U.S. metropolitan areas. Energy Policy, 56, 644-652. doi.org/10.1016/j.enpol.2013.01.034

Appendix

Table 7 Green occupation definitions

	GREEN GONST		GREEN
ISCO -08	ISCO title	ISCO -08	ISCO title
2111	Physicists and Astronomers		Not included
2114	Geologists and Geophysicists		Not included
2131	Biologists, Botanists, Zoologists and Related Professionals		Not included
2132	Farming, Forestry and Fisheries Advisers		Not included

2133	Environmental protection professionals	2133	Environmental protection professionals
2142	Civil Engineers		Not included
2143	Environmental engineers	2143	Environmental engineers
2164	Town and traffic planners		Not included
2263	Radiation protection expert		Not included
3131	Power production plant operator		Not included
3132	Incinerator and water treatment plant operators	3132	Incinerator and water treatment plant operators
3143	Forestry Technicians		Not included
3257	Environmental and Occupational Health Inspectors and Associates		Not included
9611	Garbage and recycling collectors	9611	Garbage and recycling collectors
9612	Refuse sorters	9612	Refuse sorters
	Not included	1120	Managing directors and chief executives
	Not included	1223	Research and development managers
	Not included	1321	Manufacturing managers
	Not included	1322	Mining managers
	Not included	2149	Engineering professionals not elsewhere classified
	Not included	2631	Economists
	Not included	3119	Physical and engineering science technicians not elsewhere classified
	Not included	3141	Life science technicians (excluding medical)
	Not included	3339	Business services agents not elsewhere classified
	Not included	7119	Building frame and related trades workers not elsewhere classified
	Not included	7233	Agricultural and industrial machinery mechanics and repairers
	Not included	7411	Building and related electricians
	Not included	9329	Manufacturing laborers not elsewhere classified
	Not included	9622	Odd job persons