Which Region to Choose for Implementing a Country's Industrial Policy?

An Empirical Research Path to Highlight Regional Restructuring Opportunities

Marco Capasso, Eric James Iversen, Antje Klitkou and Tore Sandven

NIFU

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Preface

This Report presents the findings from an exploratory analysis financed by the FORINNPOL-programme (project no. 271925/O50) and the BIONÆR-programme (project no. 244249) under the Research Council of Norway (RCN). The main purpose of the FORINNPOL-programme is to expand and improve the knowledge base for use in the design and implementation of research- and innovation policy by relevant actors. In doing so, the programme has financed a handful of scoping papers which seek to pave the ground for future avenues of research in the field. Our study constitutes one of these papers, and explores research avenues that can help policymakers to assess regional capabilities for "green" economic restructuring. It seeks to harmonize inputs from the innovation studies literature on the product space within the framework of the economic geography studies on regional boundaries.

The study has been carried out by Marco Capasso as project leader, in collaboration with Eric James Iversen, Antje Klitkou and Tore Sandven, all researchers at the Nordic Institute for Studies in Innovation, Research and Education (NIFU). The team would like to thank all the participants to the NIFU workshop on Industrial Dynamics (NIFU, Norway, September 2017), to the FORINNPOL Reference Group meeting (RCN, Norway, November 2017), to the 3rd EAEPE Research Area [X] "Networks" workshop (University of Bremen, Germany, November 2017), and to the Bioeconomy in Transition seminar (Unitelma Sapienza University of Rome, Italy, December 2017) for useful comments and suggestions, and RCN for financing the project. We do hope that the study is useful in itself and that it opens up for future research projects in this area.

Oslo, May 2018

Espen Solberg   Marco Capasso
Head of Research   Project leader

Contents

Summary

Addressing climate change is one of the grand societal challenges of our time. It requires a concerted effort of innovation, industrial and environmental policy. In order to achieve green restructuring at regional level, which constitutes an essential element of sustainability transitions, transformation processes must occur across the entire innovation chain, with policy setting the direction of the restructuring processes. Our study explores research avenues that can help policymakers to assess regional capabilities for "green" economic restructuring. It seeks to harmonize inputs from the innovation studies literature within the framework of the economic geography studies on regional boundaries.

The use of network analysis for the elaboration of regional policies has become a frequent theme within the theoretical context of evolutionary economic geography. The economic and industrial composition of regions can be represented as a set of nodes, which are connected by knowledge flows and whose position in such network determine the sectors' innovative activity and growth. Knowledge flows are not directly observable; therefore, data on labour flows, co-occurrence of production and co-occurrence of exports have recently been employed to define the technological proximity and the skill relatedness among economic sectors. If a structure of potential knowledge flows within a region is inferred, the regional authorities can get ideas of the sectors to be targeted with specific policies, in order to address development for the whole region through a "smart specialisation".

We argue that the fast developments which occurred in this research area in recent years require both some homogenization and some extension. Homogenization is needed to ensure that a network analysis would be able to encompass the different types of relatedness among sectors, with attention not only to intangible flows, as in terms of knowledge and innovation potential, but also to tangible flows, in terms of the intermediate goods and capital endowments which constitute the inputs and the outputs of each sector. In this sense, we envision research paths encompassing both market transactions and externalities, and both input-output analysis and innovation system research. Extensions of the research breadth would also be required to accommodate the dynamic nature of regional

evolution, where path dependence co-exists with external impulses, and the progressive positioning of regional clusters in global value chains, which feeds the importance of international trade considerations in the definition of regional policies.

After exploring the relevant literature and suggesting new pathways for empirical research on regional policy, we provide empirical examples of possible translations of the considerations above into statistical devices. Our point of departure is the construction of a network of skill relatedness among economic sectors in Norway, based on intersectoral labour flows (years 2008-2014). The suitability of different sector-specific policies for regional development is then assessed on the basis of the industrial composition of each of the 161 Norwegian labour market areas. Particular attention is devoted to environmentally relevant sectors as potential targets for regional policy, to understand which regions can provide the right embedding environment for activities in "green" innovative sectors. In our final empirical example, we show the potential of international trade firm-level data for understanding input-output relations in a policy-relevant sector. The formation of local value chains could indeed result from industrial policies which, informed on the past international transactions of firms in an emerging sector, bring to the local level input-output connections that have previously been international.

The presented approach may be enriched. Other data resources can be utilized in new and fruitful ways to address issues related to the build-up and recombination of knowledge capacities at the regional level during economic restructuring. The intersection between international trade data and regionalized patent activities in related technology fields constitutes a promising line of study. Finally, additional input-output considerations could be drawn on the basis of regional-level maps of natural endowments.

1 Introduction

Policymakers face a range of difficulties as they seek to prioritize the long-term yet innovative solutions necessary to address "societal challenges" such as climate change (see Foray, David, & Hall, 2009; Mowery, Nelson, & Martin, 2010). Policymakers require a theoretically grounded and empirically robust way to direct public policy interventions in a "smart" way. The paper develops an approach that can help policymakers to assess the potential for regions to move into industries that are growing up around renewable energy systems and the circular bioeconomy. In order to promote "green" economic restructuring in this sense, the approach builds on insights (e.g. on industrial branching and related-variety) and tools (particularly network analysis of the labour flows) from economic geography.

Green restructuring is an essential element of sustainability transitions. It requires transformation processes across the entire innovation chain: on the supply side through investments in innovation and demonstration activities, and on the demand side through public procurement policies and policies that change consumption and investment patterns. Policy has a potentially important role to play in setting the direction of the restructuring processes, going much further than traditional policy of market failure fixing, and smart specialisation strategies (Mazzucato, 2016).

Norway is presented as a potentially instructive case-in-point in this setting. Norway has an established record of investing in innovative areas of the "green economy" and a reputation as a forerunner for "sustainable development"[1]. This seems to contrast with the country's status as an advanced oil producer and its position as a top ten petroleum exporting nation. However, this tension (between brown and green economies) can (and does) act as a resource in the country's ongoing pursuit to diversify the economic activity.

Indeed, Norway has a long term aim to diversify from the dominant and mature (if not yet declining) petroleum industry and to find ways to leverage national capabilities and resources into emerging industries that are growing up around re-

[1] The Brundtland Commission on 'sustainable development' (1987), named for the Norwegian prime minister at the time, has become something of a touchstone for Norway's environmental focus.

newable energy systems and the circular bioeconomy. Our paper develops an approach that can help direct policy attention as it pursues this aim. We use labour flow data to identify potential complementarities between related industrial structures at the regional level. The approach is aimed to support and inform policy development in this context. Following Boschma and Gianelle (2014), the framework of smart specialisation is used to consider ways to stimulate new industries to connect to inter-related industries across regions, particularly in cases where growth paths may be hindered by "cognitive constraints". In our empirical examples, we specifically draw attention to some key sectors of the Norwegian economy like renewable energy and urban waste management.

The paper is organized in the following way. The second section surveys the empirically oriented literature of economic geography to introduce policy concerns and approaches to address these. The third section illustrates how labour flows, in connection with input-output considerations, can be used to identify potential for regional diversification into green industries. The fourth section shows how international trade data can help identifying strategic inputs in policy-targeted sectors. The final section considers how this approach can be used within the smart specialisation policy framework and it discusses some extensions.

2 From data to information: reflections on the previous literature

2.1 The state of the region

A policy for regional restructuring should be based on knowledge about the capabilities embedded in the current economic composition of the region. Economic capabilities - in terms of technology, skills and natural resources - are integral to how sectors emerge across regions - in terms of firms and employment - and, ultimately, how regional economies perform over time. Thus, the sectoral composition of the region stands out as an ideal starting point for the policy-maker (to think about restructuring). Each economic sector can be depicted as a different circle in a region's economic set, ideally circumscribing the firms and employees operating in the sector. Some capabilities may not correspond to only one sector, especially at higher levels of aggregation, but there are always capabilities that are sector-specific; therefore, a first rough approach to the capabilities of the region would entail some measurement of the current activities that a region has within each sector, as proxied, for instance, in terms of employment or turnover.
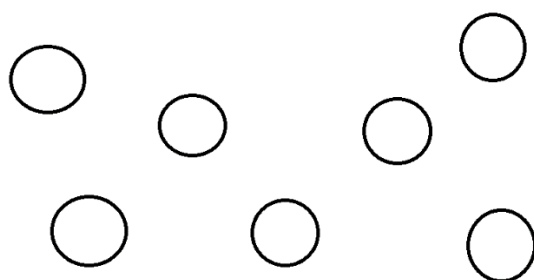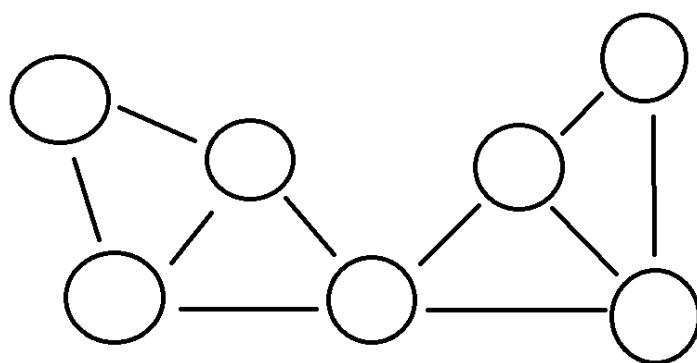
**Figure 1 Economic sectors in a region.**

A second reason to use economic sectors as the units of our regional analysis lies in the channels that the regional policy will ultimately be able to utilize. If the policy instruments are going to affect different firms (incumbents or entrants), a first way to group the target firms is by the type of products and processes they deal with, which in turn defines roughly the economic sector to which the firms belong. The economic sector (old or new) can represent the best unit for a policy target in that it indicates a function within the regional supply chains. The level of aggregation at which sectors should be considered is closely linked to the level of aggregation at which we want the policy to act: for instance, a feasibility analysis for a regional policy devoted to fostering the production of photovoltaic panels implies a fine sectoral disaggregation after which the regional current status should be examined.

Figure 1 illustrates how individual economic activities may be grouped into subsets (i.e. the circles) once they are associated with specific economic sectors. Each subset can then be construed to be a node in a network, where two nodes are seen to connect if the knowledge exchange between them is deemed to contribute to innovation and growth based on established criteria. Adopting a geographic terminology, we qualify as "proximate" any two economic sectors between which a knowledge exchange can be fruitful. While such proximity could be measured in technological terms, for instance through an analysis of co-patenting (Tanner, 2014), in the rest of this paper we assume that proximity depends mainly on skill-relatedness across sectors. This assumption, based on the idea that a transfer of knowledge across sectors can be fruitful if the skills employed in the two sectors partially overlap, captures an important aspect of the regional innovation processes, and allows us to refer to practical examples of possible empirical research, without undermining our general theoretical framework. A direct consequence of the assumption is to utilize data on past cross-sectoral labour flows to infer skill-relatedness across sectors and, in network terms, to build connections among nodes, as in Figure 2.

Figure 2 Potential knowledge flows across sectors.

Once the connections are built, the visualisation of the potential knowledge flows across the economic sectors in the region allows a first assessment about how a regional policy, targeted at a particular sector, can spread its effects throughout the whole economy, in terms of innovation and, consequently, of growth. Moreover, the analysis of the network, and the construction of indicators about the centrality of each node within the network, provides a hint about which nodes can be considered strategic for keeping knowledge flowing throughout the economy.
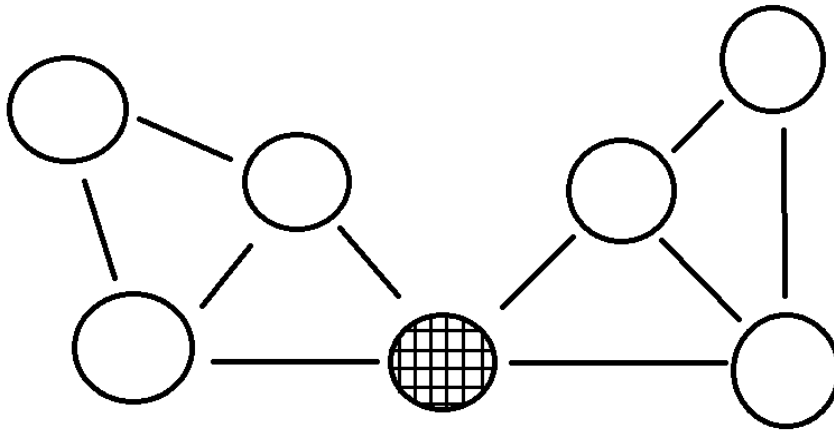
Figure 3 Strategic position.

The chequered node depicted in Figure 3 has a high "betweenness centrality" (Freeman, 1977) and thus appears to play an important role in the knowledge network of the region; the corresponding sector could be seen as strategic to ensure that knowledge flows are not constrained into a subset of the regional economy. A decline, and possible demise, of the regional activities in that sectors should thus be avoided through a targeted policy, while, if we assume that the "chequered" sector is not sufficiently represented yet in the region, the regional policy could incentivise the growth of that sector into a hub for future knowledge exchanges in the region.

2.2 Policy goals and industrial dynamics

A question addressed at a regional policymaker might be "which sector would most benefit the region" rather than "which sector would most benefit *from* the region". Therefore, when pondering the strategic relevance of an economic sector, we should not focus simply on the possibilities of growth of the target sector, but we should apply equal, if not higher, weight to the contribution of that sector to growth in other sectors of the regional economy. A researcher could argue that the two goals, even if separate from a political point of view, could be achieved by the same policy in many practical cases, given that a node which occupies a central position in a network is usually supposed to benefit from many different flows across the network. However, this is not the case when networks are directed. If directions are imposed on the connections in Figure 3, then a directed network can emerge as in Figure 4, where the chequered node appears as a destination of flows instead of an origin.
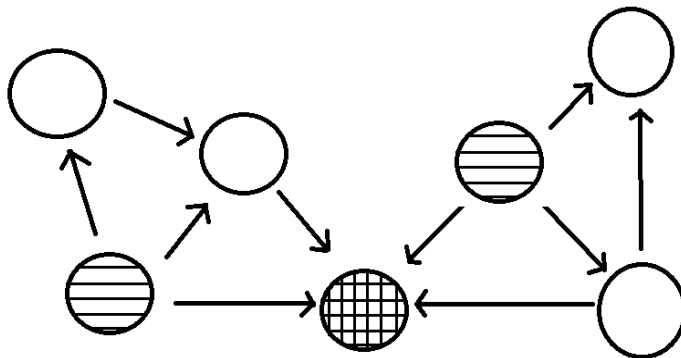
Figure 4 Directed network.

Recent empirical works on regional innovation systems (see, e.g., Fitjar & Timmermans, 2017) have depicted directed networks to represent knowledge flows among economic sectors. At the same time, Boschma (2017) has mentioned the explicit consideration of asymmetric relations across economic sectors as a pillar for new strands of scientific literature in regional studies. We argue that the move from undirected to directed networks in the representation of regional econ-omies would force policymakers to refine the boundaries of their goals, since a sector in a strategic position for its own growth may not appear any longer as a sector in a strategic position for the growth of the region as a whole. For the case of Figure 4, a policymaker might well decide to invest in the two "striped" eco-nomic sectors instead of the "chequered" economic sector, whose position seemed to be strategic within the undirected network of Figure 3, but not any longer in the directed network of Figure 4.

Apart from the "strategic for whom?" question, there is also a "strategic when?" question that needs to be answered by empirical research studies, in order to provide policy advice. In scientific terms: the view of the regional potential given by a static network analysis of the regional composition can be partial. For instance, suppose that activities in a given sector of the regional economy are currently declining. For simplicity, consider the undirected network of Figure 3, where knowledge connections are symmetric, and assume that declining sector corresponds to the top-right node. There are two sectors directly connected to the declining sector, and many more which are indirectly connected. As a consequence, the decline may propagate throughout the regional economy, by a diffusion process which is likely to be progressive but not instantaneous: first, the knowledge in the neighbouring sectors will be affected (and the associated innovation rates), then, in the longer run, also sectors which are far away in the regional network might be negatively influenced.
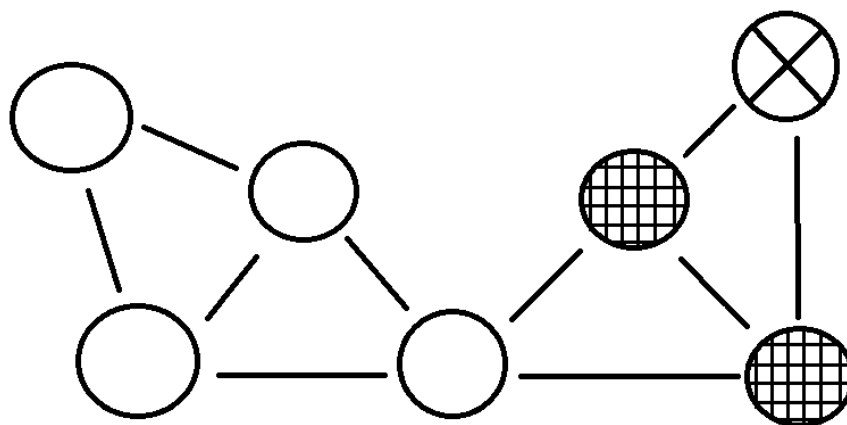
Figure 5 Percolation.

In such a dynamic context, the regional policy could target economic sectors which may not be central to the network in a traditional time-independent sense, but which are important in a dynamic sense since they might aid the diffusion of the economic crisis throughout the whole regional economy. Novel network analysis indicators like "percolation centrality" (Piraveenan, Prokopenko, & Hossain, 2013) could then be used, which take into account not only the network topology of the intersectoral relations, but also the current growth or decline of each economic sector. More in general, sectors which are "neighbours" of a declining sector (as the two "chequered" nodes in Figure 5 are neighbours of the top-right "crossed" declining sector) could be considered as strategic for the development of a region, even if they are not characterized by a high betweenness centrality, since a policy targeted at them could stop the sectoral decline, especially in terms of knowledge loss, to propagate throughout the rest of the economy.

2.3   Factors of production and economic circularity

An additional reason for considering the chequered nodes to be strategic in Figure 5 lies outside the context of knowledge dynamics. Instead, it connects to the nature of the data used to infer the knowledge dynamics itself: labour flows are also important "per se" and not only for inferring skill relatedness among sectors. If the regional authorities keep aggregate employment among the policy-relevant goals, then, in the wake of an employment decline occurring in a sector, a major concern would be for the rapid reallocation of dismissed workers. As a consequence, the observation of past heavy flows of employees between the currently declining sector and the chequered nodes would also suggest that the "chequered" nodes in Figure 5 might easily absorb the workers dismissed from the declining sector. In case the chequered sectors are expanding, they could temporarily gain from the decline of the neighbouring sector by attracting the brightest employees. The regional authorities could thus elaborate a strategy to best complement the labour force, become potentially available to the chequered sectors, with policy-driven fixed and financial capital.

   Moreover, the authorities would want to consider the economic consequences, for the region, of the satellite activities gravitating around the target sectors. In the same way that a target sector may attract a factor of production like labour from other economic sectors present in the region, the same target sector could attract intermediate goods from within the region, either directly through immediate suppliers, or indirectly, and from all the other actors situated upstream along the supply chain. Input-output analysis should arguably be used to measure the induced effects of a restructuring policy from the upstream sectors of the supply chain, on the basis of the quantity of intermediate goods that are supposed to be requested in order to satisfy the increased sector-specific activity pushed by the policy. In Figure 6, we represent input-output relations among sectors as dashed arrows, edged toward the buying sector. In some cases, they may overlap with the knowledge relations (depicted through solid segments), and in other cases they may not, due to the fact that buyers can be distant from suppliers in terms of skills and technology, while knowledge flows may not depend on market transactions (Dietzenbacher & Los, 2010; Martin, 2017; Montresor & Marzetti, 2009).
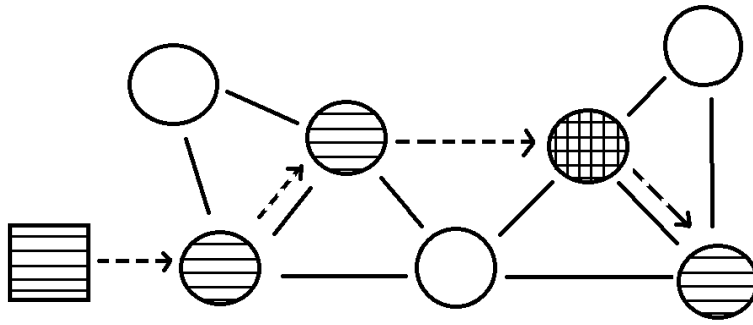
Figure 6 Input-output relations.

Input-output tables are often built at the national level, but the knowledge of the regional industrial composition can complement them for assessing the overall effect of a region-sector specific impulse (see, e.g., Giannakis & Bruggeman, 2017). If the task of the researcher is to assess whether the impulse should be given at all, as for the case of an *ex ante* policy assessment, then a view on the upstream layers of the supply chain would be needed to judge the feasibility of the policy, that is to understand whether and to what extent a policy impulse on the target sector can translate into a persistent growth of the same sector, given the constraints in terms of inputs available in the region. If the target sector is situated in the upper layers of a supply chain, then the availability of natural resources in the region (depicted as squares in Figure 6) could be of primary importance for the success of the policy.

Three considerations are necessary here. First, while it is useful, for the sake of our exposition, to refer to supply chains with two defined ends (respectively, one upstream and one downstream), we must still keep in mind that the economy is, at least to some extent, circular: also in the sense that the extraction of natural resources itself require some inputs, while the waste from final consumers can itself become an input. The technical writings on input-output analysis, as well as their theoretical foundations, acknowledge such circularity (Leontief, 1928; Sraffa, 1960).

Secondly, input-output tables may not include new economic sectors, or can be obsolete when a sector is characterized by a high innovation activity (possibly spurred by the policy itself). This problem can be circumvented by reflecting on the fact that the innovation process, driven by the policy, will alter the direct links of the target sector more than the connections which are represented as distant in the chain. Indeed, an analysis of the distant connections, even if based on past economic transactions and input-output considerations, could still be effective; the direct links, instead, should be reshaped on the basis of novel technical analyses of the needs of the renewed target sector. So, if a new technology is introduced in a region for which no economic records are available, the researcher could build a

"bill of goods" (see, e.g., Bess & Ambargis, 2011) for the target sector, in the sense that technical experts would assess what direct inputs might be needed for the new technology, and accordingly reshape the direct links in the input-output network (i.e. the dashed lines around the chequered node in Figure 6).

Thirdly, the downstream effects of the policy should not be underestimated. Innovation in the target sector translates into new products, and/or in different prices for old products. This includes also valorisation of by-products which earlier have not been valorised and ended as waste or which achieved only low prices because of a limited market for these by-products and limited technological solutions to up-grade them. Some (by-)products need to find a market in the same region because it would be too expensive to transport them to other regions. Opportunities can be created, within the regional economy, also for firms that do not belong to the target sector but that may benefit from a reduction in the cost of inputs for current production lines (also possibly creating new production lines). Such downstream effect along the supply chains could acquire even more relevance than the upstream effect, if the target sector is made of "specialized suppliers" (see, e.g., Castellacci, 2008; Pavitt, 1984).
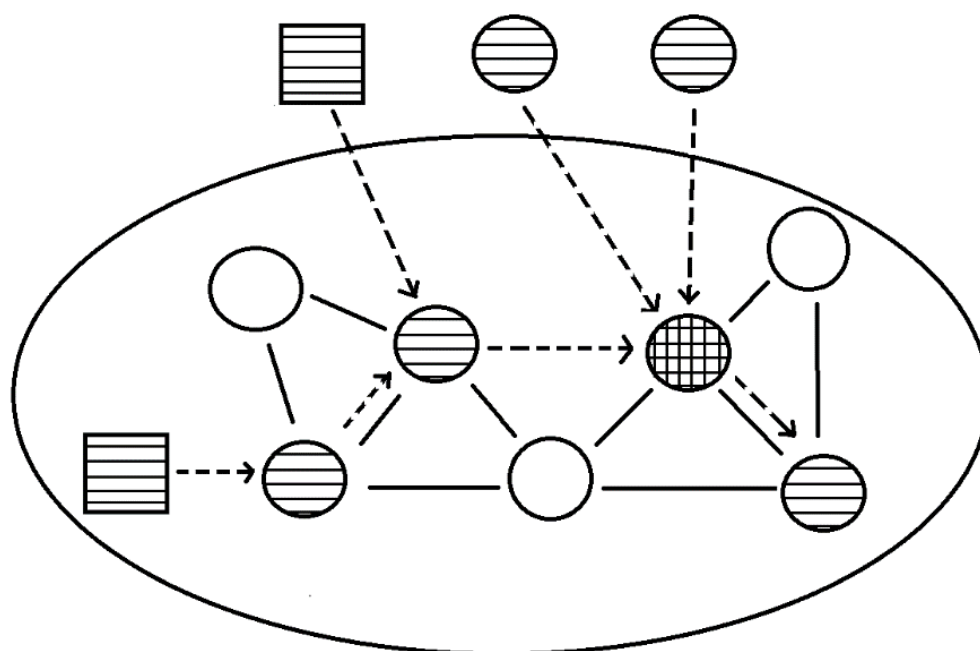
Figure 7 Interregional and international trade.

2.4   The region as an open economy

Input-output tables are usually built from primary data referring to capital flows, rather than to quantities of goods. Recorded transactions indicate the flow of money from a buyer to a supplier, which provides a measure of the value transferred from the supplier to the buyer. At each stage of the supply chain, some value is added, corresponding to the difference in value between the inputs and the outputs; in a closed economy, the gross value of inputs to a target sector represents the sum of values added within the economy. Increasing what is known about the chain, in terms of additional information about the value added by a given node of the chain, can be relatively uninteresting to the policymaker. However, when the economy has a high degree of openness, as is the case for a regional economy, it becomes essential to capture the amount of value entering or exiting the economy; in other words, the "leakage" in the input-output intraregional structure becomes overwhelming important (North, 1955; Thirlwall, 1980).

For the purpose of empirical analysis, it is convenient to distinguish transactions that are solely interregional from those that also involve an international component. Details over transactions among regions within a country are rarely available to researchers. If the country were a closed economy, a shift-share analysis could extrapolate information over a region's competitiveness, by comparing the evolution of the region's economic composition with the changes in the nationwide composition (Dunn, 1960). However, a traditional shift-share analysis is insufficient to assess and predict regional competitiveness when the reference markets are supranational (Chiang, 2011; Fotopoulos, Kallioras, & Petrakos, 2010).

Instead, the increasing availability and use of customs data, which provide information of firm-level international transactions at a high level of product disaggregation (see, e.g., Bricongne, Fontagné, Gaulier, Taglioni, & Vicard, 2012), opens a range of new opportunities for regional analysis. On the one hand, it suggests new clues about the position of a region in the global supply chains, hinting at the possibilities for future vertical integration. On the other hand, it shows the type of markets in which the region is competing with other, possibly foreign, regions, thus hinting at possible directions of smart specialisation according to a region's comparative advantage.

Moreover, this data-source provides a platform to better understand the regional economy. It allows us to appreciate the relationship between a given region's current outputs (goods and services) and the inputs that it currently sources internationally. This in turn allows us to think about other outputs that the region could potentially have. Not only could the existing trade channels allow the production and sale of new goods, but they could also signal a useful connection to foreign knowledge sources, thanks to overlaps between knowledge flows and trade flows (Boschma & Iammarino, 2009). Particular significance, for triggering

growth in innovative sectors, should be attributed to the knowledge embedded in imported capital goods, which could cover a current lack of local skills (Barba Navaretti, Galeotti, & Mattozzi, 2004; Mody & Yilmaz, 2002).

International trade data, which are derived from customs data on international transactions, have the additional value of being strongly disaggregated, e.g. at a 6-digit level, according to the type of good traded. On the contrary, input-output tables for national flows are traditionally available at a high level of aggregation, typically at the 2-digit level. Such a limitation also affects the newly developed "world input-output tables", which describe connections among 2-digit sectors located in different countries. Such tables can allow one to derive network properties of international macroeconomic flows (Cerina, Zhu, Chessa, & Riccaboni, 2015; Contreras & Fagiolo, 2014), but they can hardly provide scientific support for fine-grained industrial policies. On the other side, databases such as United Nations COMTRADE provide highly disaggregated information about trade flows (6-digit level). This rich data can be used to understand the evolution of a country's export mix from the sectoral point of view (see Hausmann, Hwang, & Rodrik, 2007; Hidalgo & Hausmann, 2009). The problem with trade data however is that the geographic data is only available at the national level. This is a limitation. Therefore, we advocate the concurrent use of customs data on international flows, which detail international transactions for each firm at a high product disaggregation, and business register data, which allow a subnational geographic referencing of the firms' activities (e.g. as proxied by the employment across different establishment).

3 Potential knowledge networks in regions: Two empirical examples on biogas production and on wind power

3.1 Motivation for focusing on biogas production and wind power

Green restructuring is an essential element of sustainability transitions. It requires transformation processes across the entire innovation chain: on the supply side through investments in innovation and demonstration activities, and on the demand side through public procurement policies and policies that change consumption and investment patterns. Policy has to set the direction of the restructuring processes, going much further than traditional policy of market failure fixing, and smart specialisation strategies (Mazzucato, 2016). As has been pointed out by Gibbs and O'Neill (2014) a definition of a "green economy" has to be a combination of different economic activities, such as "agricultural and natural resources conservation; education and compliance; energy and resource efficiency; greenhouse gas (GHG) reduction, environmental management and recycling; and renewable energy" (Gibbs & O'Neill, 2014, p. 206).

The 'green restructuring' of the Norwegian economy requires a prioritisation of specific directions of innovation towards turning the fossil-based economy into a circular and 'green' economy, with appropriate skills and resources at firm level as well at regional level, and a change of demand-side policy, including green procurement and inducement of changed user needs. In times when the decline of the fossil-based economy is characterised also by major job losses, the transferability of skills across occupations becomes an issue. The new "green" jobs require other skills than non-green jobs. Consoli, Marin, Marzucchi, and Vona (2016) have pointed out that green occupations exhibit a stronger intensity of high-level cognitive skills than non-green jobs. They require often more formal education, more work experience and more on-the-job training (ibid.).

The energy sector in general is characterised by large technical systems which are rather rigid and resistant to change (Hughes, 1987). The complexity of the energy sector and high costs invested in infrastructure make it to a difficult target for radical changes. When comparing sustainable energy clusters with other types of industry clusters in an U.S. context, McCauley and Stephens concluded that sustainable energy clusters are more diffuse and lack clear defining technologies since they can include beside energy production also transportation, construction industry etc. (McCauley & Stephens, 2012). This complexity is mainly related to processes leading to increased energy efficiency in buildings, consumption, transport and different industry processes. The development of sustainable energy clusters is supported by activities in the public domain, both at national and regional/local level, such as by economic incentives for renewable energy production, by greenhouse gas emissions targets, through public procurement requirements and public R&D expenditures for sustainable energy (ibid.).

A country which over the last years has been discussed extensively in the academic and political discourse about the transition towards sustainability is Germany with its "Energiewende". Kutschke et al. addressed the importance of locational factors for the performance of the German energy sector (Kutschke, Rese, & Baier, 2016). They concluded that the quantity and quality of skilled labour has been highly relevant throughout the whole development process of energy innovation projects, even higher than demand conditions (Kutschke et al., 2016, p. 9).

In this chapter, we specifically draw the attention on two sectors of the Norwegian economy, respectively connected to two sources of renewable energy: biogas and wind. In particular, we will imagine the case that new policies promoting biogas production and wind power will have to be implemented in Norway. We will show that both knowledge flow analyses and input-output considerations may highlight which Norwegian regions are best suited for the policies' implementation.

3.2 Background of the wind power industry in Norway

The Norwegian electricity production and consumption is totally dominated by renewable energy, mainly by hydro power. Nevertheless, Norway has large endowments for producing also wind energy, especially offshore wind energy, but this is not much exploited. These endowments have not been exploited because of several reasons: (a) electricity is rather cheap in Norway and investors fear for the profitability of investments, (b) offshore wind instalment at the Norwegian coast are much more expensive than in other regions of Europe because of deep waters and heavy weather conditions, (c) the Norwegian energy ministry does not

prioritize deployment of offshore wind technology in Norway, and (d) the competencies for offshore wind are drawn back into offshore oil and gas. The renewable electricity from offshore wind could be used for electrifying the oil and gas production, it could be used for electrifying the transport sector (both road transport and ferries), and it could be used for functioning as a battery for Europe. The lacking home market for offshore wind does not provide much help for establishing a clear path creation for offshore wind energy in Norway (Steen & Karlsen, 2014). This is contradictory to the extensive funding of R&D projects for offshore wind technology by the Norwegian government over the last decade (Njos, Jakobsen, Fosse, & Engelsen, 2014). The Norwegian offshore wind sector is dominated by actors from the oil and gas sector, in addition come some major energy companies and companies from the maritime sector. These actors are aiming for reutilizing historically developed capabilities and for supplementing their core activities (Hansen & Steen, 2015). However, these actors are mostly still engaged in their core activities. On the other side, it has been shown that knowledge and skill flows from the mature oil and gas sector cannot be reduced to patents and technology, but include as well operational experience, value chains, business models, and routines (Steen & Hansen, 2014).

We can compare the lacking deployment of offshore wind technology in Norway with the development of offshore wind in other countries, such as Germany, Denmark and the UK (Piirainen, Tanner, & Alkaersig, 2017). The countries had different starting points and followed different trajectories: Denmark and Germany follow a turbine manufacturing-based transition, the UK's development is based on rapid increase in installed capacity and Norway's development is based on a diversification of offshore oil and gas (ibid.). In the UK, the adoption of offshore wind technology has been driven by three policy objectives: (a) lower carbon emissions, (b) improved energy security, (c) providing new manufacturing jobs (Graziano, Lecca, & Musso, 2017). While the two first objectives have been accomplished – the UK has become a large adopter of this technology, the creation of manufacturing jobs related to offshore wind has not been a success. As an explanation for this failure, Graziano et al. (2017) highlight that in comparison to Spain, Denmark and Germany in the UK no industrial policy support has been given. Therefore, the UK has to import wind technology from Germany, Spain and even Norway.

3.3 Background of the biogas production industry in Norway

In the second empirical example of this chapter, we will concentrate on biogas production from organic waste streams. In Norway, the origin of organic waste streams can be (1) municipal organic waste streams from private households, grocery stores, hotels, etc., (2) waste streams from the food processing industry, (3) waste streams from agriculture (i.e. manure from cattle and pigs), (4) waste streams from aquaculture, and (5) waste streams from the pulp and paper industry. When selecting a gasification pathway, the results are biogas which can be upgraded to be used as a transport fuel, replacing fossil fuels, and a digestate which can be used as a fertilizer in agriculture and gardens, replacing mineral fertilizer or peat. Because the transport of the digestate to other regions would be too costly the selection of the gasification pathway is dependent on the possibility to deploy the digestate in the region, which means a specialisation in agriculture.

Beside the production of biogas, the incineration of organic waste is much more common, both in Europe and in Norway (Lausselet et al., 2017; Lausselet, Cherubini, Serrano, Becidan, & Stromman, 2016). This path has been selected quite often to address two main challenges: (1) the European commission has banned the use of landfills for organic waste streams, and (2) the incineration of such waste streams allows the production of non-fossil energy in the urban areas (Munster & Meibom, 2010; Uyarra & Gee, 2013). The incineration pathway has been chosen by many Norwegian municipalities because of the ban on landfill. However, with putting the circular economy on the stage the European commission is more oriented to higher value creation from such waste streams. And this has been an argument for a number of Norwegian municipalities to work with different biogas solutions, often based on cooperation between several municipalities to achieve the necessary size to achieve efficiency and enough feedstock. There are also examples where municipal organic waste is processed together with industrial food waste and manure (Lyng et al., 2015). And more recently the combination of waste streams from the pulp and paper industry with waste streams from aquaculture at Skogn in Trøndelag provide another option for producing biogas from organic waste.

3.4 Preliminary data treatment: sectoral knowledge proximity from inter-sectoral national labour flows

To elaborate our examples, we use the linked employee-employer data from Statistics Norway (2017b). The data at the individual employee level cover all persons in Norway between the age of 15 and the age of 75. Furthermore, the data include an employer variable in the form of a unique firm identifier where the employee works. If a person is employed by more than one firm, the person is registered as employed by the firm where he or she works most hours a week.

The Statistics Norway data register the situation in one given reference week each year. We can thus register if an employee has moved to a different firm from this particular week in a given year to the reference week 12 months later. We do not know if there have been any further movements within this 12-month period.

For the 6-year period 2008-2014, we register all employees who moved from one firm to another from one year to the next, e.g. from 2008 to 2009, and we cross-classify them by the industry they left in the previous year and the industry they entered in the subsequent year. We include here movements within the same industry. As a result, all these inter and intra industry flows are added up for each of these six consecutive pairs of years to make up a total of inter (and intra) industry labour flows for the whole 6-year period 2008-2014.

Industry is here defined by the Nace classification system, and the labour flows are tallied at the 2-, the 3- and the 4-digit Nace levels[2]. Firms are here defined at the individual plant or establishment level, rather than at the enterprise level. The enterprise is here the legal unit, and may comprise several establishments. The definition of industry is also related to the establishment level.

The observed flows of persons between industries are compared to the flows which would have been expected if flows between industries were random, i.e. if no pair of industries were more tightly connected in terms of labour flows than other pairs of industries. The expected number of persons moving from industry i to industry j is calculated as the total number of persons moving out of industry i (to any industry) multiplied by the total number of persons entering industry j (from any industry), divided by the total number of movers (from any industry to any industry):

*expected flow from industry i to industry j = total out of i * total entering j / total number of movers*

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[2] This system is hierarchical: the 4-digit categories are sub categories of the 3-digit categories, which in turn are sub categories of the 2-digit categories.

For the flow of employees between any pair of industries *i* and *j*, we may define a relatedness ratio as the ratio between observed and expected flow of employees:

Ratio$_{ij}$ = observed$_{ij}$ / expected$_{ij}$

If this ratio is above 1, the flow between the two industries is larger than what we would have expected if the labour flow among industries were random.

    This ratio varies from 0 to infinity and is thus highly skewed. This may be normalised to vary between -1 and 1 through the following transformation:

Rationorm$_{ij}$ = (Ratio$_{ij}$ - 1) / (Ratio$_{ij}$ + 1)

(the same standardization is used in the section "Regional Skill Relatedness" in Fitjar & Timmermans, 2017).

To get a rough impression of whether the difference between the observed frequency in a given cell and the expected frequency given a null hypothesis of statistical independence (*H$_0$*) is statistically significant, we use the *adjusted residuals* test for each cell, as suggested by Alan Agresti (see p. 31 in Agresti, 1996). The adjusted residuals are defined as:

$$Adjres_{ij} = \frac{observed_{ij} - expected_{ij}}{\sqrt{expected_{ij}(1 - \frac{sumin_j}{sumtotal})(1 - \frac{sumout_i}{sumtotal})}}$$

According to Agresti, 'an adjusted residual that exceeds about 2 or 3 in absolute value indicates lack of fit of *H$_0$* in that cell,' i.e., lack of fit with a null hypothesis of statistical independence; in our analysis, we will use a threshold of 3. This test is only valid for 'large samples,' and Agresti suggests that a 'large sample' in this connection is one where the expected frequency in the cell in question is at least 5; in our analysis, we will use a threshold of 10.

    We should here note that no account is taken of the problem of clustering in the data. People do not just work individually in this or that industry. In most cases they work in firms together with several other people. For different reasons and in different ways, they will often also move together with other people. This emphasizes the point that the adjusted residuals measure here only should be taken as a rough indicator of statistical significance.

3.5 Preliminary data treatment: regional economic composition from establishment-level employment

We compute the distribution of employees across industries in all regions in Norway for year 2014. For the definition of regions, we use the 161 labour market regions constructed in Juvkam (2002). The classifications are made both at the Nace 2-digit, 3-digit and 4-digit levels; we will first use 2-digit and then 4-digit in our analysis. Only employees between 18 and 65 years of age, who worked at least 20 hours a week, are included.

We calculate the number of employees in each industry in each region we would have expected if the distribution of employees across industries were the same in each region as it is in the country as a whole. For industry i in region j it is calculated as:

*Expected$_{ij}$ = total industry i * total region j / total national employment*

If the observed number of employees is higher than this expected number, then this particular industry is overrepresented in this region; if it is lower, the industry is underrepresented. In exactly the same way as with the labour flows, we construct a ratio between observed and expected, and we normalise this ratio to get a measure which varies between -1 and 1. Unlike for the labour flow case of the previous subsection, we do not evaluate a significance measure of the ratio: we will simply consider a sector i as overrepresented (underrepresented) in a region j if the corresponding normalized ratio (we may call it a "normalised sectoral representation ratio") is higher (lower) than zero.[3]

3.6 First empirical example: targeting biogas production with a 2-digit sectoral analysis

Suppose now that the national government of Norway wants to promote the production of biogas in a region which is not currently specialized in the production of energy. In this case, we would primarily want to consider regions where the supply chain already is already (partially) located and, preferably, where potential upstream, complementary and downstream sectors are already present. Finally, we would like the policy to be applied in a region where the production of biogas could contribute well to the knowledge flows in the region, including the knowledge interchanges among sectors which do not occur through market transactions.

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[3] Similar approaches have been used in the literature on "economic base analysis" (see, e.g., Haig, 1927; Hoyt, 1961) and "revealed comparative advantage" (Balassa, 1965).

A rough way to pursue the three policy goals above could be operationalized through an *Input-output restriction*, bringing a focus on the regions where local supply chains can be envisioned, and a *Knowledge centrality ranking*, to understand which regions could benefit the most from the policy-target sector in terms of contribution to intraregional knowledge flows.

1) *Input-output restriction*: for the biogas example, a policy could, for instance, aim at localizing supply chains where urban waste is used to produce biogas (upstream connection), and biogas is then used to fuel public transport vehicles (downstream connection).

Among the 161 labour market regions in Norway, the input-ouput restriction would translate into considering regions where:

- Electricity, gas, steam and air conditioning supply (2-digit industry code: 35) is underrepresented (this would be the target sector to be promoted by the policy);
- at least two sectors, among Sewerage (37), Waste collection, treatment and disposal activities; materials recovery (38), Remediation activities and other waste management services (39) and Scientific research and development (72), are overrepresented (potential upstream and complementary sectors);
- Land transport and transport via pipelines (49) is overrepresented (potential downstream sector).

A sector *i* is considered as overrepresented (underrepresented) in a region *j* if the corresponding normalised sectoral representation ratio, defined above in Section 3.2, is higher (lower) than zero.

The restriction above holds for five regions: Fredrikstad/Sarpsborg; Askim/ Eidsberg; Kongsvinger; Gjøvik; Stryn.

2) *Knowledge centrality ranking*: the five regions above can be ranked according to the "betweenness centrality" index that the target sector "Electricity, gas, steam and air conditioning supply" (2-digit industry code: 35) would receive within the network of potential knowledge flows in the region.

It is important to point out one aspect of this ranking step. In each region, we consider as existing nodes of the network all the 2-digit sectors that are overrepresented in the region in terms of employment, i.e. for which the normalised sectoral representation ratio, as defined above in Section 3.2, is higher than zero. To these existing nodes, we add another node: the target sector, which is currently underrepresented; this is because we want to imagine what its position would be if it were to be overrepresented following our policy.

The network connections among the nodes - in other words, the potential knowledge flows among the sectors - are inferred on the basis of labour flows,

considering also statistical significance as in the procedure stated above in Section 3.1. In particular, we consider two sectors i and j as connected if (see definitions in Section 3.1): $Rationorm_{ij} > 0.25$; $Adjres_{ij} > 3$; expected frequency > 10.

On this constructed network, which is different for each region because each region has different "overrepresented" sectors, we assess the potential centrality of the target sector. For simplicity, in this paper we use the original "betweenness centrality index" described in the seminal article by Freeman (1977). However, more refined measures could be advised as well, depending on the context of application. For instance, a "flow betweenness" measure, as in Freeman, Borgatti, and White (1991), would be especially useful when a weight can be assigned to each connection in the network. If, instead, the network nodes were divided into subgroups, e.g. on the basis on their sector code first digit, then the "brokerage role" of the target sector could be analysed, as in Gould and Fernandez (1989), to understand whether the target sector could assume a special function by connecting different node groups.

After building a network of potential knowledge flows within each of the five regions above, we obtain a "betweenness centrality index" that is equal, respectively, to: 0 for Fredrikstad/Sarpsborg; 0 for Askim/Eidsberg; 0.11 for Kongsvinger; 0.06 for Gjøvik; 0 for Stryn.

Kongsvinger and Gjøvik would look as interesting candidates for the production of biogas: let's see why. Both overcome the input-output restriction by already having two potential upstream sectors ("Sewerage" and "Waste collection, treatment and disposal activities; materials recovery") as well as the potential downstream sector "Land transport and transport via pipelines".

As shown in Figure 8, Kongsvinger could benefit from a policy boost to the sector 35, i.e. to "Electricity, gas, steam and air conditioning supply", which could channel knowledge to sectors already well represented like 24 ("Manufacture of basic metals"), 42 ("Civil engineering") and 61 ("Telecommunications") while bridging also knowledge from sectors 20 ("Manufacture of chemicals and chemical products"), 38 ("Waste collection, treatment and disposal activities; materials recovery") and 82 ("Office administrative, office support and other business support activities"). In other words, the target sector "Electricity, gas, steam and air conditioning supply" could take on an important role in channelling knowledge throughout the whole region.
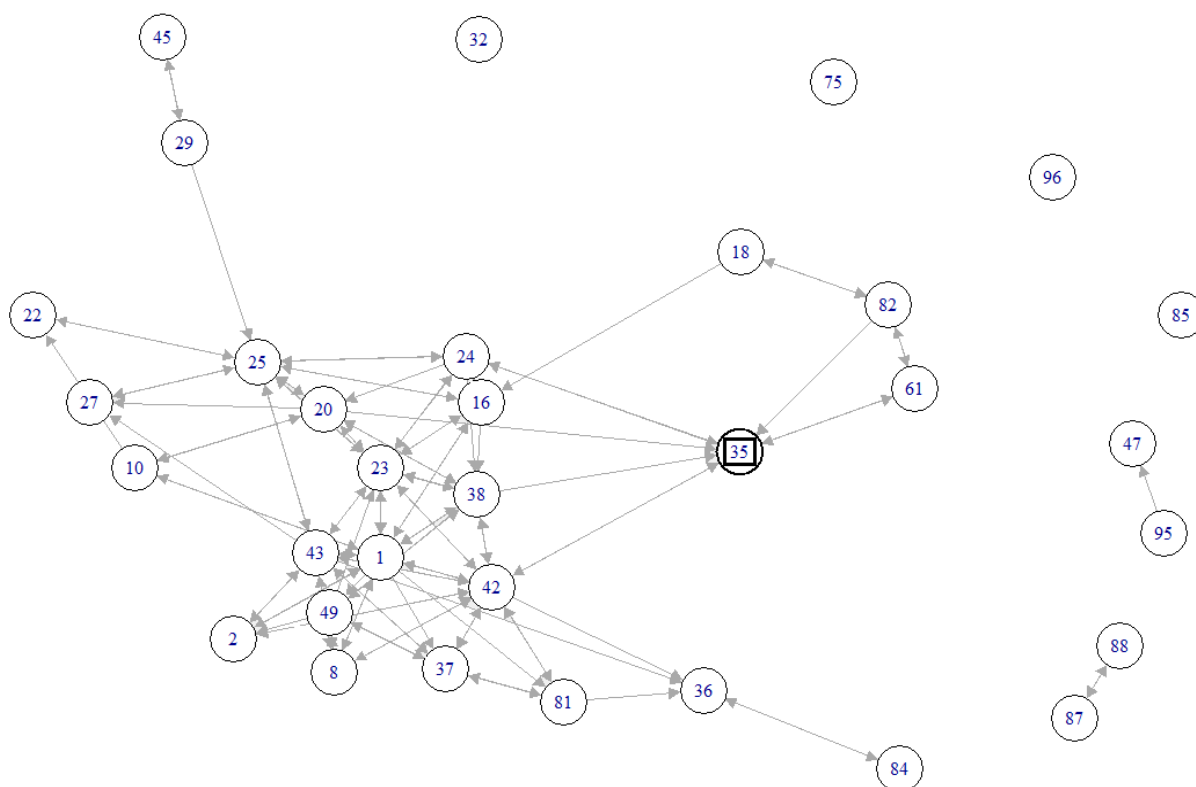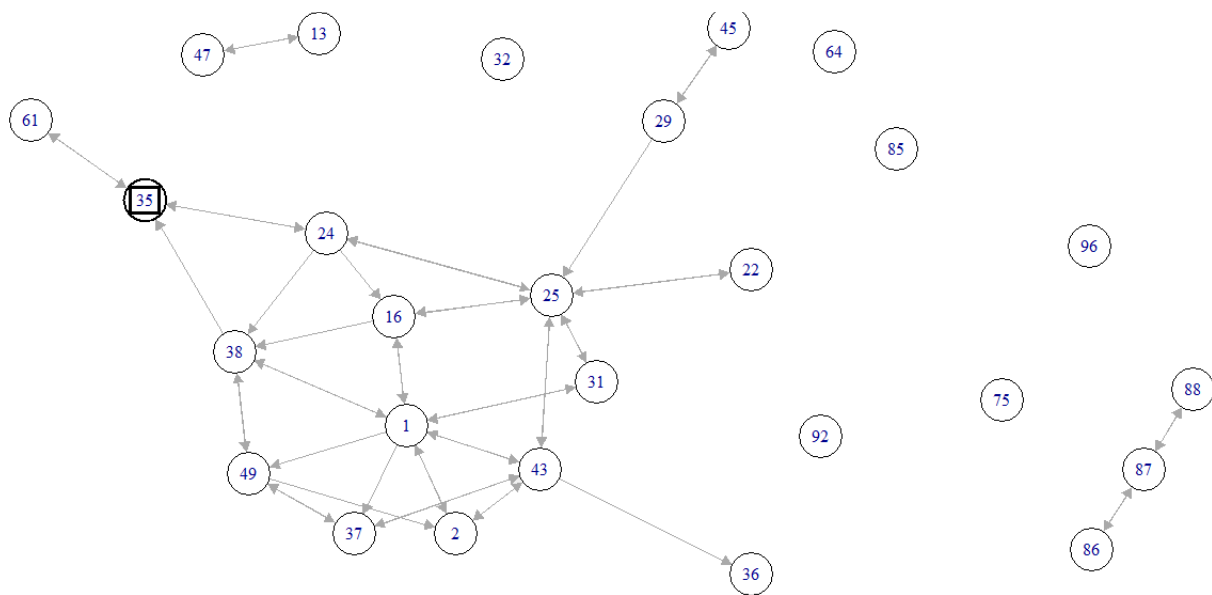
Figure 8 Kongsvinger potential knowledge network.
Source: own calculations based on data from Statistics Norway (2017b).

In Gjøvik, the target sector "Electricity, gas, steam and air conditioning supply" could still be a candidate knowledge hub, but its contribution to the region would be limited by a more peripheral position in the network (see Figure 9). This is also due to the fact that, in Gjøvik, the "neighbouring" node 61 ("Telecommunications") is currently isolated, whilst, in Kongsvinger, sectors like 18 ("Printing and repro-duction of recorded media") and 82 ("Office administrative, office support and other business support activities") serve to connect "Telecommunications" to the other areas of the regional knowledge network. As a result, the fact that Gjøvik does not currently have a strong representation of the sectors 18 and 82 might limit the strategic role that the target sector 35 ("Electricity, gas, steam and air conditioning supply") could play in the region following the policy.
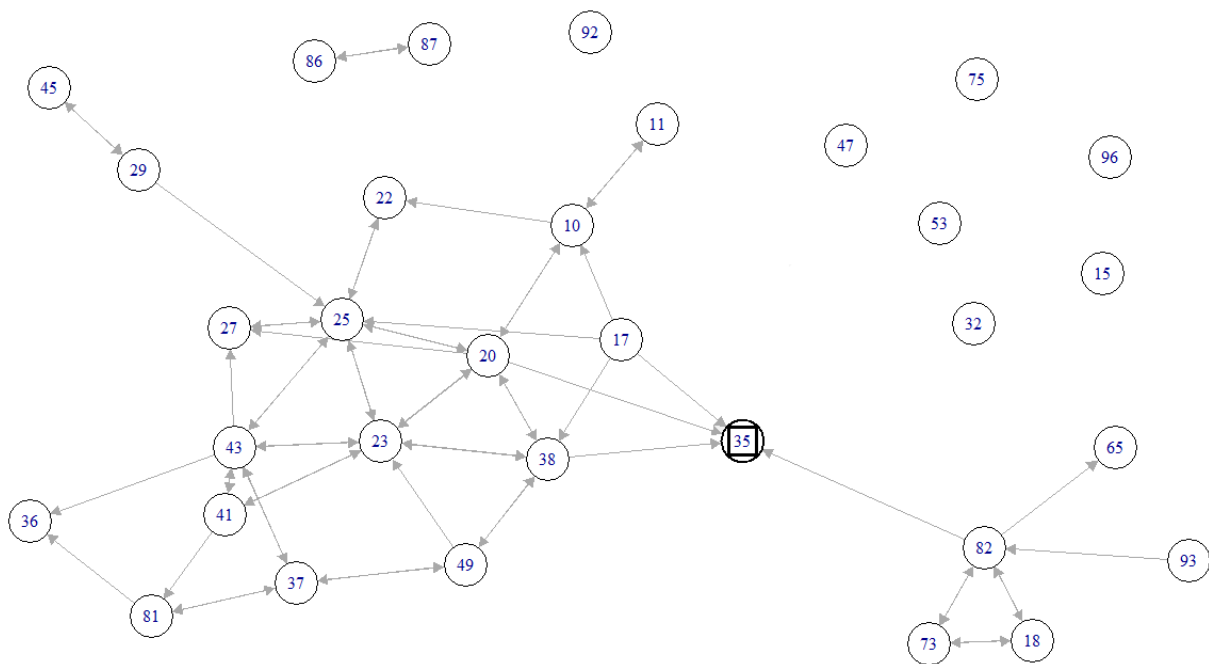
Figure 9 Gjøvik potential knowledge network.

Source: own calculations based on data from Statistics Norway (2017b).

For comparison, Figure 10 shows how the potential knowledge network would look in the Fredrikstad/Sarpsborg region. At a first glance, the target sector 35 would seem to occupy a more central position than in Gjøvik. However, the position is central only in terms of inflows: many sectors could bring knowledge to the target sector 35, but they would not symmetrically receive knowledge. In other words, the current knowledge stock of region could help the growth of the target sector, but such growth would not correspondingly facilitate the spreading of knowledge across the other sectors already present in the region. Therefore, the Fredrikstad/Sarpsborg region constitutes an exemplary case to show the importance of "directed" networks, and "asymmetric" intersectoral relations, in the analysis of potential knowledge flows.

Figure 10 Fredrikstad/Sarpsborg potential knowledge network.

Source: own calculations based on data from Statistics Norway (2017b).

3.7 Second empirical example: targeting wind power production with a 4-digit sectoral analysis

For our second empirical example, we choose to consider a finer sectoral disaggregation, where both the input-output restriction and the knowledge network analysis are applied at the level of 4-digit industrial sectors. the policy goal in this second example is the promotion of wind power production in regions which currently have an underrepresentation of production of electricity, but which could have a direct downstream utilization of electricity in energy-intensive processing.

1) *Input-output restriction*: among the 161 labour market regions in Norway, we consider regions where:

- Production of electricity (4-digit industry code: 3511) is underrepresented (this would be the target sector to be promoted by the policy);
- at least two sectors, among Manufacture of engines and turbines, except aircraft, vehicle and cycle engines (2811), Transmission of electricity (3512), Distribution of electricity (3513) and Trade of electricity (3514), Construction of utility projects for electricity and telecommunications (4222), and Engineering activities and related technical consultancy (7112), are overrepresented (potential upstream and complementary sectors);

- at least one sector, among Manufacture of other inorganic basic chemicals (2013), Aluminium production (2442) and Other non-ferrous metal production (2445), is overrepresented (potential downstream sector).

A sector *i* is considered as overrepresented (underrepresented) in a region *j* if the normalised sectoral representation ratio, as defined above in Section 3.2, is higher (lower) than zero.

The restriction above holds for three regions: Kongsvinger; Arendal; Molde.

2) *Knowledge centrality ranking*: the three regions above can be ranked according to the "betweenness centrality" index that the target sector "Production of electricity" (4-digit industry code: 3511) would receive within the network of potential knowledge flows in the region (built as in the previous subsection, apart from the finer 4-digit level of sectoral disaggregation).

After building a network of potential knowledge flows within each of the three regions above, we obtain a "betweenness centrality index" that is equal, respectively, to: 0 for Kongsvinger; 0 for Arendal; 0.0024 for Molde. Molde would thus look like an interesting candidate for the production of wind power: let's see why.

Molde gets past the input-output restriction because it already has three potential upstream sectors ("Distribution of electricity", "Construction of utility projects for electricity and telecommunications" and "Engineering activities and related technical consultancy") as well as one potential downstream sector ("Manufacture of other inorganic basic chemicals").
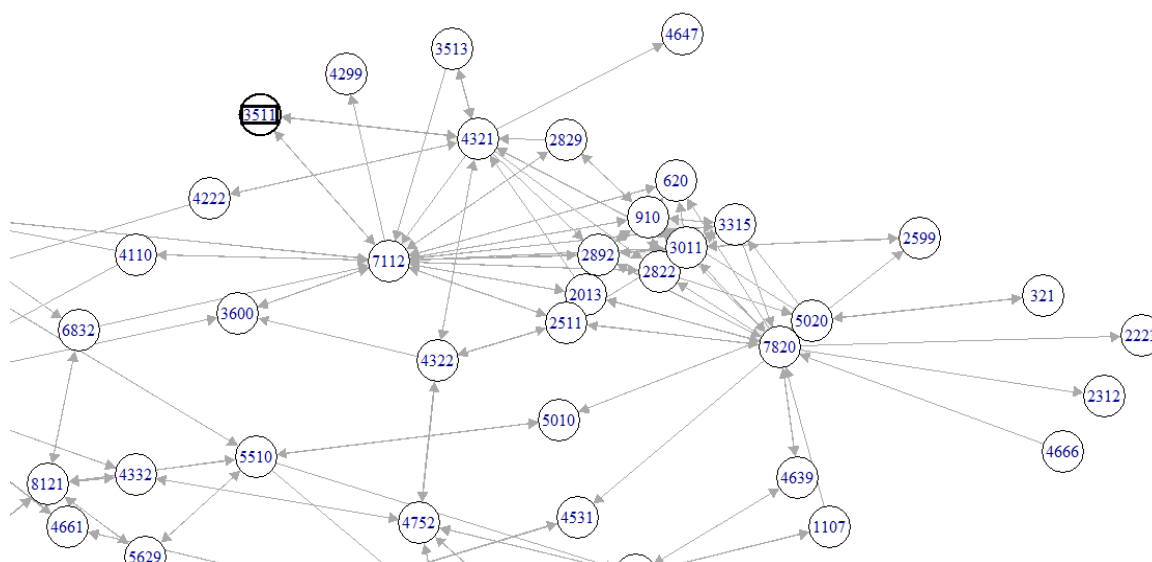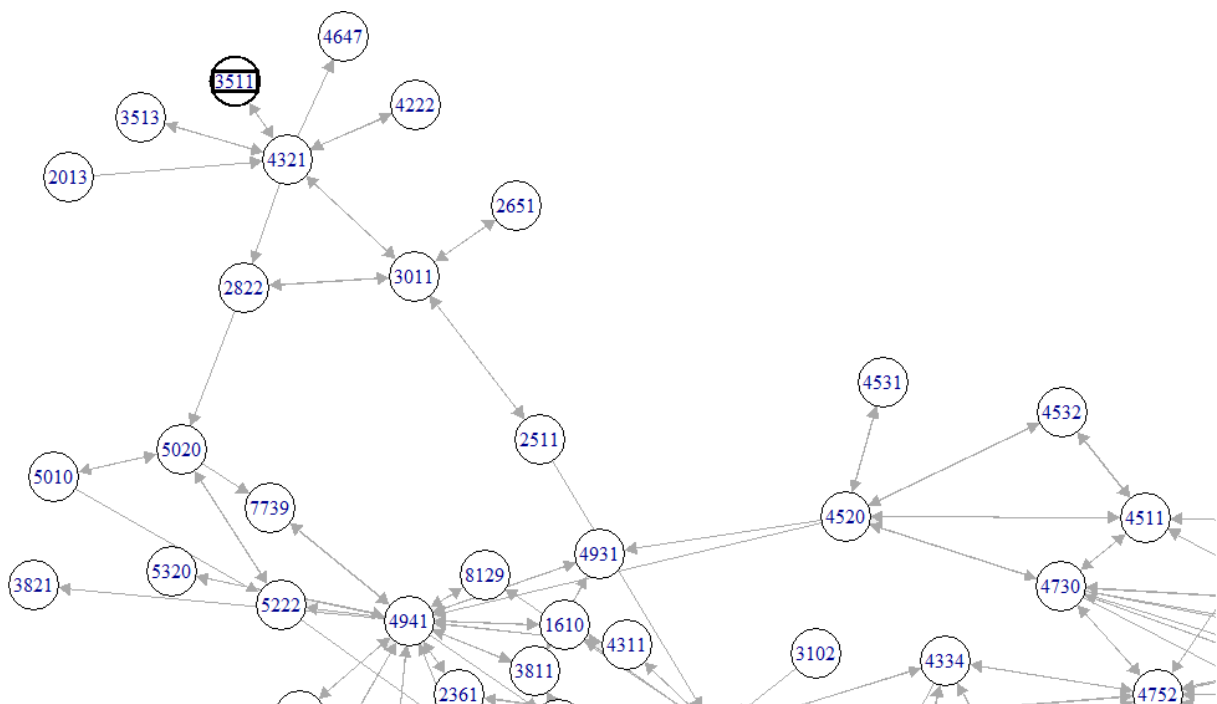

Figure 11 Molde potential knowledge network (detail).

Source: own calculations based on data from Statistics Norway (2017b).

As shown in Figure 11, Molde could arguably benefit from a policy boost to the sector 3511, i.e. to "Production of electricity", which could bridge the knowledge already flowing to 7112 ("Engineering activities and related technical consultancy") towards 4321 ("Electrical installation") and the sectors connected to it.

In Arendal, instead, 7112 ("Engineering activities and related technical consultancy") is not currently well represented, and therefore a policy promoting 3511 ("Production of electricity") would not bridge knowledge coming from other sectors present in the region (see Figure 12). The contribution to the whole network, occurring through the contribution of 3511 to 4321 ("Electrical installation") would thus be limited. This is the case, despite the fact that Arendal satisfies the input-output restriction: the potential upstream and complementary sectors "Distribution of electricity" and "Construction of utility projects for electricity and telecommunications", as well as the potential downstream sector "Manufacture of other inorganic basic chemicals", are indeed already well represented in the region.

Figure 12 Arendal potential knowledge network (detail).

Source: own calculations based on data from Statistics Norway (2017b).

4 Policy hints from international trade data: An empirical example on the photovoltaic industry

4.1 Introduction

In the previous chapter, we have suggested a two-step procedure for choosing the best regions where to implement an industrial policy; as examples, we considered environment-related policies aimed at the production of respectively biogas and wind power. Our procedure first excluded regions having a lower possibility of providing physical inputs to the industrial sector of interest, and then looked for regions where the targeted sector could "bridge" knowledge between other local sectors. This second step, inspired by the empirical literature on evolutionary economic geography (see e.g. Boschma & Gianelle, 2014; and Fitjar & Timmermans, 2016), inferred potential knowledge connections among sectors on the basis of national intersectoral labour flows. The first step was instead based on input-output considerations: we searched for regions having already some existing activity in sectors which could provide important inputs to the policy-targeted sector. However, understanding which inputs could be qualified as "important" for an emerging sector was left to technical reflexions, also given the traditional difficulty of a systematic use of input-output data when a high level of data disaggregation would be needed (see e.g. Bess & Ambargis, 2011).

In this chapter, we show how the first step of our procedure can be made more solid, by inferring potential input-output local connections on the basis of international trade data related to a targeted industrial sector. The new procedure relies, at the same time, on firm-level international trade data and on linked employer-employee data, in order to capture the potential local relations of an economic sector targeted by an industrial policy. We will consider the case of a policy aimed at stimulating activities in the photovoltaic sector in Norway, and in particular we will try to provide a suggestion for regions in Norway which could benefit the most

by the policy. The example is meant to show how the contemporaneous use of different types of quantitative data brings to the surface regional features which could otherwise remain undetected.

4.2 Motivation for focusing on the photovoltaic industry

Why have we selected the photovoltaic industry as a case for analysing the usefulness of trade data for assessing regional capabilities for green economic restructuring? First, solar photovoltaics is clearly a part of green restructuring because it has contributed to a larger share of renewable energy capacity installed in the world. Second, Norwegian companies have represented a major share of the global photovoltaic industry, also after the financial crisis which contributed to the closure of many other Western PV companies. Third, Norwegian companies have been located in different regions of Norway (Northern Norway, Central Norway, Capital region and Southern Norway), often close to hydropower plants, and have connected to existing competencies in pre-existing processing industries. Fourth, close trade links have been established to foreign markets: through import of machinery and equipment from Europe for the automated production lines of the Norwegian PV companies, through the delivery of silicon grade from subsidiaries in the U.S. to wafer companies in Norway, and through the export of solar cells to European and Asian countries. Fifth, the largest Norwegian PV companies are still located in Norway, but their relations have swung to Asia, especially to China and Singapore, through ownership structures and through international deliveries between subsidiaries.

However, the use of photovoltaic to showcase this use of trade data faces a number of obstacles. These obstacles are related to the complex structure of the value chain of photovoltaics and to how photovoltaic products are defined in the trade data (see below). There exist many different intermediary products which may be traded in the value chain, either domestically or internationally. Since Norwegian firms may have been involved in providing these products, there are potentially many domestic transactions that cannot be traced to the international trade data.

As a result, the definition of the photovoltaic products becomes somewhat blurred and requires fine tuning. We acknowledge these obstacles, but we think that such obstacles can be addressed and will probably also to be found in other industries. An alternative would be to start with an industry that has few or no intermediate products and just a few final products to be traded. But this would rather be an exception than the rule.

4.3   Background of the photovoltaic industry in Norway

The Norwegian processing industry boasts a long tradition that started over a century ago based on the exploitation of hydropower. This started with two companies, the Elektrokemisk Industri, later named Elkem for processing of different metals, and Norsk Hydro for processing nitrogen to produce fertilizer. For photovoltaics, we focus here on Elkem. Elkem specialised in the production of different silicon materials, such as ferrosilicon, which is used for strengthening steel constructions, and microsilica, which is a by-product of silicon production and a valuable additive for concrete and cementitious products. The company has since the 1970s attempted to produce solar grade silicon for the solar PV industry (Klitkou & Coenen, 2013). The firm developed a totally new process technology, also due the increased global demand for silicon for PVs in the 1980s, mainly in Japan and Germany.

Since the mid-1990s, a number of Norwegian firms sprung out of Elkem; these firms laid the basis for an emergent PV industry that covered the whole value chain from the production of silicon, to wafers, solar cells, solar modules and instalment and operation of PV plants.

Several notable cases deserve to be mentioned. The first is the Renewable Energy Corporation (REC) which grew to have subsidiaries both in Norway and abroad. In addition, the former owner of REC also founded Scatec and, in 2005, Norsun, a firm specialised in manufacturing mono-crystalline silicon ingots and wafers for the international market. At the same time, or soon after, other companies were founded which provided necessary equipment for the PV industry, including equipment for recycling of different by-products and with repair of solar cells.

The industry enjoyed high government funding for R&D projects and networks (Klitkou & Godoe, 2013), but the deployment of solar PV in Norway was not prioritised by the energy ministry because of the existence of hydropower capacity. The PV industry was mainly oriented towards the export market and not towards a domestic market, which is a parallel to the offshore wind industry. However, since the value chain of the PV industry requires interaction between different companies and their subsidiaries, there exist also transactions between domestic actors, and not just towards the international market.

With the boom of the solar PV industry in China, prices of solar PV declined rapidly and many strong actors outside China went bankrupt. One exemption was Elkem, which still is at the forefront of technology development, was taken over in 2011 by Chinese Bluestar and has since then expanded also in Norway. REC closed all manufacturing capacity in Norway and focussed only on its huge plant in Singapore. Chinese Bluestar bought in 2015 also REC Group and merged Elkem Solar and REC Group into one company, since February 2018 named REC Solar Norway.

4.4 Identification of firms in the photovoltaic industry through firm-level export data

In order to elaborate a regional policy connected to the PV industry, we want to understand which inputs may be important for developing PV products. Looking at the imports of firms involved in the PV industry can provide a hint at important inputs required by the industry. However, to classify a firm as involved in the PV industry is itself a challenge: we need to circumscribe a set of firms having a similar bundle of output goods, appearing at least partially as exports in the international trade data, in order to give meaning to an analysis of their inputs. Identifying "PV firms" on the basis of a NACE code would not constitute a reliable first step: we need to know clearly which type of output is produced in order to give a meaning to the corresponding input mix. Failing on this first step of the analysis, by comparing inputs bought by firms producing totally different types of outputs, could create an avalanche of mistakes in the following steps.

Our approach is to identify the type of output that a firm produces in order to give a meaning to the corresponding input mix. The question we face is which output good to focus on, as a typical output of the photovoltaic industry? This section discusses steps that were involved in making this choice.

Our identification strategy aimed to zero in on a recognizable solar PV industry via the two lenses, namely:

1. the industrial categories (NACE) of the Norwegian enterprises and their subsidiaries nationally;
2. the trade classifications (e.g. SITC) of the goods (and services) being traded by those entities.

In our first step (not reported here), we explored the standardized trade-classifications to see how well their usage of relevant terms (e.g. 'photovoltaics') fit with what we know about the industry in Norway. The categories however (e.g. 85414000) proved unreliable in narrowing in on the industry.

We then started a search for the right categorisation using SITC codes (Standard International Trade Classification, Rev. 3). Here is the sub-group 776.3 including the basic heading 776.37 Photosensitive semiconductor devices; light-emitting diodes.

See the full hierarchy here:[4]

- Section: 7 - Machinery and transport equipment
- Division: 77 - Electrical machinery, apparatus and appliances, n.e.s., and electrical parts thereof (including non-electrical counterparts, n.e.s., of electrical household-type equipment)

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[4] https://unstats.un.org/unsd/cr/registry/regcs.asp?Cl=14&Lg=1&Co=776.37

- Group: 776 - Thermionic, cold cathode or photo-cathode valves and tubes (e.g., vacuum or vapour or gas-filled valves and tubes, mercury arc rectifying valves and tubes, cathode-ray tubes, television camera tubes); diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices; light-emitting diodes; mounted piezoelectric crystals; electronic integrated circuits and microassemblies; parts thereof
- Subgroup: 776.3 - Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices (including photovoltaic cells, whether or not assembled in modules or made up into panels); light-emitting diodes
- Basic heading: 776.37 - Photosensitive semiconductor devices; light-emitting diodes.

For analysing products related to solar grade silicon, we also identified the subgroup 522.2 ("Other chemical elements") with the basic heading 522.23 ("Silicon"). See the full hierarchy here:[5]

- Section: 5 - Chemicals and related products, n.e.s.
- Division: 52 - Inorganic chemicals
- Group: 522 - Inorganic chemical elements, oxides and halogen salts
- Subgroup: 522.2 - Other chemical elements
- Basic heading: 522.23 – Silicon

However, in SITC we could not identify a specific product code for solar grade silicon. There are many different silicon products. We identified the code for ferrosilicon (SITC 671.51), another silicon-based product produced and traded by Elkem. See the full hierarchy here:

- Section: 6 - Manufactured goods classified chiefly by material
- Division: 67 - Iron and steel
- Group: 671 - Pig-iron, spiegeleisen, sponge iron, iron or steel granules and powders and ferro-alloys
- Subgroup: 671.5 - Other ferro-alloys (excluding radioactive ferro-alloys)
- Basic heading: 671.51 – Ferrosilicon

Since the PV industry includes so many steps in the value chain we decided to concentrate for the purpose of this report just on trade related to solar grade silicon.

The key players in Norway's PV industry described in Klitkou and Coenen (2013) were characterized by the 4-digit NACE code "2013" (NACE description: "Manufacture of other inorganic basic chemicals"), which is also associated to the production of silicon. Therefore, exploiting the one-to-one association between 4-digit CPA codes and 4-digit NACE codes, we checked which tariff codes were associated to the export transactions classified by the CPA 2013 code. It resulted that,

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[5] https://unstats.un.org/unsd/cr/registry/regcs.asp?Cl=14&Lg=1&Co=522.23

in the years under consideration, a high share of the value of exports in CPA 2013 coded goods (40% of the total in year 2011) was associated to the tariff code 28046900 (i.e. "Silicon, containing pure silicon for less than 99,99% of the weight"). We decided then to concentrate our analysis on the production of silicon, with the focal tariff codes of 28046100 and 28046900, both related to SITC 522.23.

The two tariff codes are used by us when scanning the firm-level international trade data: we identify all the Norwegian firms which have exported, in the years between 2009 and 2015, one or both the corresponding types of silicon. Those are the firms which we will focus on to infer possible input-output relations in the PV industry.
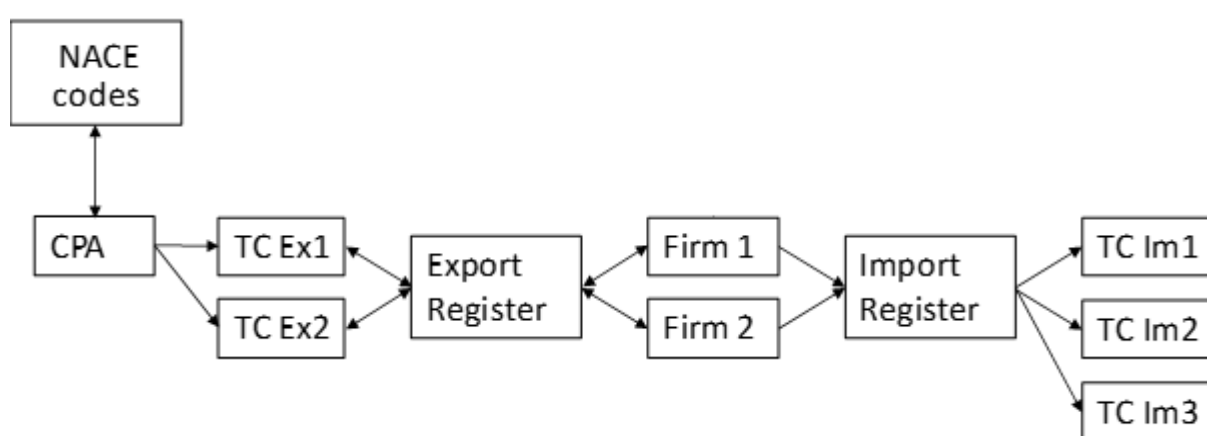
Figure 13 Overview over alternative strategies for analysing trade data based on product codes or NACE codes.

Note: NACE= Statistical Classification of Economic Activities in the European Community, CPA=Classification of products by activity, TC= Tariff codes.

Figure 14 shows the volume of export and import for all Norwegian companies which have exported two types of silicon products in year 2011: silicon with a content of at least 99.99% weight silicon (CPA 28046100) and silicon with a content of less than 99.99% weight silicon (CPA 28046900). The actual values are not so important here, since we use this information only to show how the information about the firms' exports can be traced back to the information about the imports of the same firms.
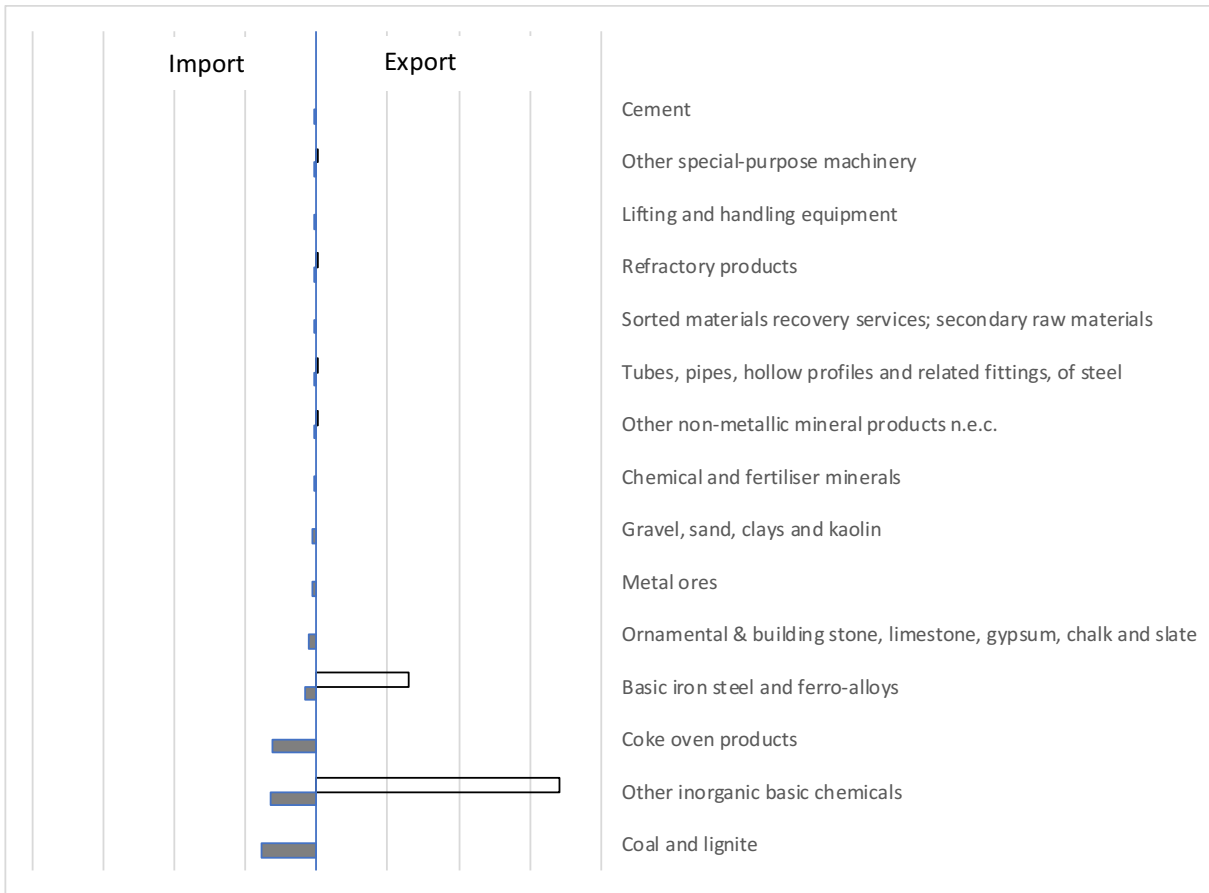
Figure 14 Imports and exports of all Norwegian firms exporting two types of silicon products in 2011.

Note: The two product codes are silicon with a content of at least 99.99% weight silicon (product nr. 28046100) and silicon, with a content of less than 99.99% weight silicon (product nr. 28046900).

4.5 Application to regional policy elaboration: Input-output restriction

In chapter 3, we have outlined a two-step procedure to help selecting regions for a policy of national interest. The first step consisted in applying an "input-output" restriction to restrict the set of regions that the policy could target, according to the current presence, in the regions, of industrial sectors which could provide inputs to the "policy target" sector (in our case, the photovoltaic sector). We will now apply that input-output restriction in a refined way, which will now make use of firm-level international trade data, trying first to answer the question: which Norwegian regions are best suited to provide inputs for a nascent photovoltaic industry? For the definition of regions, we have again used the 161 labour market regions constructed in Juvkam (2002). The input-output restriction is applied through the following five sub-steps:

1) For each year between 2009 and 2015 included, we identify in the firm-level external trade data of Norway (Statistics Norway, 2017a) all the firms ("foretak", in Norwegian) that have exported at least one of the following two goods, as defined by the respective 8-digit tariff codes ("varenummer", in Norwegian), chosen as described in the previous section:

- - 28046100 - Silicon, containing pure silicon for at least 99,99% of the weight
- - 28046900 - Silicon, containing pure silicon for less than 99,99% of the weight

We thus obtain a list of firm-year observations: "which firm has exported silicon in which year".

2) We exclude all the firm-year observations where, in the corresponding year, the value of the exports of the corresponding firm, for the two tariff codes above, has been lower than 50% of the value of all exports, by the same firm in the same year. This way, we focus on firms that have had silicon as main export, narrowing the risk of studying unrelated imports afterwards.

3) For the remaining firm-year observations, we isolate the five import categories, defined according to a 4-digit CPA index, which weigh the most, in terms of value, among all the 4-digit CPA categories of imports of the same firm in the same year. We thus get, for each firm-year observation, a list of five 4-digit CPA categories, which we see as likely inputs used by the firm for the production of silicon during the year.

4) We pool together, across all firm-year observations, the lists of five 4-digit CPA categories, and we obtain the following list of eight 4-digit CPA categories, ordered from the most recurrent across the firm-year observations to the least recurrent: 0500, 0811, 1910, 2013, 2445, 2410, 2790, 2890. If we had obtained a longer list, we would focus only on the most recurrent categories in the list. With the short list we obtained, instead, it looks that the firm-year observations in our data do not differ too much among themselves; we will then consider all the eight CPA categories as possible strategic input categories for the production of silicon.

In Table 1, we can read on the right column the description of the corresponding 4-digit NACE code (at 4-digit, there is a precise correspondence between CPA and NACE), which provides a suggestion of the industrial sectors which have provided the imported inputs. Notice the presence of sector 2013, which is also the sector which would be often associated to the exports we consider.

Table 1 Recurrent import categories (4-digit CPA) among firm-year observations of silicon exporters (left column) and corresponding NACE industrial sectors (right column).

CPA code	Corresponding NACE sector
0500	Mining of coal and lignite
0811	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate
1910	Manufacture of coke oven products
2013	Manufacture of other inorganic basic chemicals
2445	Other non-ferrous metal production
2410	Manufacture of basic iron and steel and of ferro-alloys
2790	Manufacture of other electrical equipment
2890	Manufacture of other special-purpose machinery

The categories 0500 and 2890 correspond to categories that could have been narrowed down according to the fourth digit, but have not been narrowed down in the firms' declarations. For 0500, we decide to consider both the two 4-digit subcategories 0510 (NACE: "Mining of hard coal") and 0520 (NACE: "Mining of lignite"). Instead, we decide to exclude the categories 0811 and 2890, since the many subcategories of "Ornamental and building stone, limestone, gypsum, chalk and slate" (0811) and "Special-purpose machinery" (2890) constitute extremely heterogeneous sets.

5) We select all the labour market regions where at least two of the 4-digit NACE sectors mentioned above are overrepresented with respect to whole Norway. In particular, following the procedure in chapter 2 and 3, we keep only the regions where at least two of the 4-digit NACE sectors, mentioned above, show an observed number of employees higher than expected, given both the regional total employment and the nation-wide industry employment (we use the most recent year available to us, 2014, in the linked employee-employer data built by Statistics Norway, 2017b).[6]

Following the previous five procedure steps, we are left with four labour market regions, where we assume that a local process of import substitution could gradually take place if a regional policy aimed at silicon production were implemented.

Table 2 shows, on the left column, the names of the four regions and, on the columns, the NACE codes of sectors that are both possible input providers and already overrepresented in the region.

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[6] Notice that, unlike in the previous chapter, we do not limit our search to regions where silicon production, i.e. the policy-targeted activity, is currently not occurring. As a consequence, we could keep in our selection also regions where silicon is already being produced.

Table 2 Labour market areas in Norway where at least two industrial sectors are present which might, in the future, provide inputs for the photovoltaic industry.

| Labour market area	Possible input-provider sectors	
Grenland	2013	2410
Kristiansand	2013	2445
Sauda	2410	2790
Odda	2013	2410

4.6 Application to regional policy elaboration: Knowledge centrality ranking

As a second step, we want to understand, for each of the four regions which have satisfied the input-output restriction, how the local intersectoral knowledge flows would be affected by a stimulated production of silicon. The stimulated production of silicon would represent a boost to the 2-digit NACE sector "20", chosen as the 2-digit version of the 4-digit sector "2013" which we have previously recognized as best associated to the exports of silicon. Therefore, we want to know, in each of the four regions, what position the NACE sector 20 (chemicals sector) occupies, or would occupy, in an ideal network of local knowledge flows among the industrial sectors represented in the region. For each region, we consider as existing nodes of the network all the 2-digit sectors that are overrepresented in the region in terms of employment (same definition of overrepresentation as in the previous section), plus the sector 20 if not already present. The network connections among the nodes - in other words, the potential knowledge flows among the sectors - are inferred on the basis of nation-wide intersectoral labour flows in the time span between years 2008 and 2014. As a measure of centrality of sector 20 in each regional "potential knowledge network", we adopt the "betweenness centrality index" suggested by Freeman (1977). Results are in table 3: the Kristiansand labour market area shows, among the four regions, the highest centrality of sector 20 in the regional "potential knowledge network". In other words, a policy stimulating the production of chemicals could in Kristiansand contribute best to bridge knowledge among the industrial sectors in the region.

Table 3 Betweenness centrality of the chemicals sector (NACE 20) for each of the four labour market areas in Norway where at least two possible input-providing industrial sectors are present.

Labour market area	Centrality of sector 20
Kristiansand	0.13496716
Odda	0.07803885
Grenland	0.06621577
Sauda	0.03015873

To better grasp an intuition of the ranking, it is interesting to give a look at the potential knowledge network in the regions of Odda and Sauda, ranked as second and fourth in Table 3. The two labour market areas of Odda and Sauda share a solid industrial tradition, they are both situated in the county of Hordaland and have both an economy less diversified than in Kristiansand. Their potential knowledge networks are shown respectively in Figures 15 and 16 and show many similarities; however, sector 20 would have a much higher centrality in Odda than in Sauda. Why is it the case? Notice that both in Odda and in Sauda Manufacture of chemicals (20) could connect with Production of electricity (35), but only in Odda could Production of electricity (35) connect with Civil engineering (42). Analogously, notice how in Odda Manufacture of chemicals (20) is an important connector for the knowledge coming from Manufacture of fabricated metal products (25), while, in Sauda, Manufacture of fabricated metal products (25) occupies a more central position in the potential knowledge network. These small differences in the network topology lead to a much higher centrality of the chemicals sector in Odda, and could give one argument for preferring Odda over Sauda as a target for a regional policy aimed at silicon production.
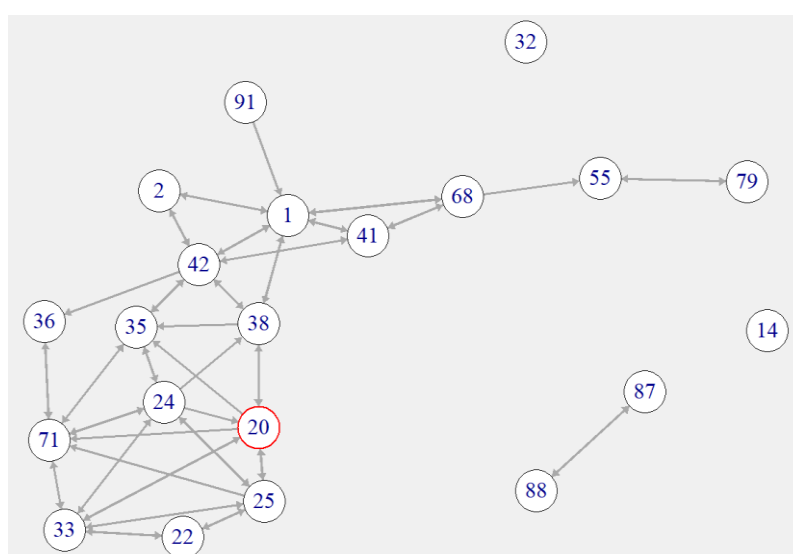
Figure 15 Potential knowledge network for the Odda labour market region.

Source: own calculations based on data from Statistics Norway (2017b).
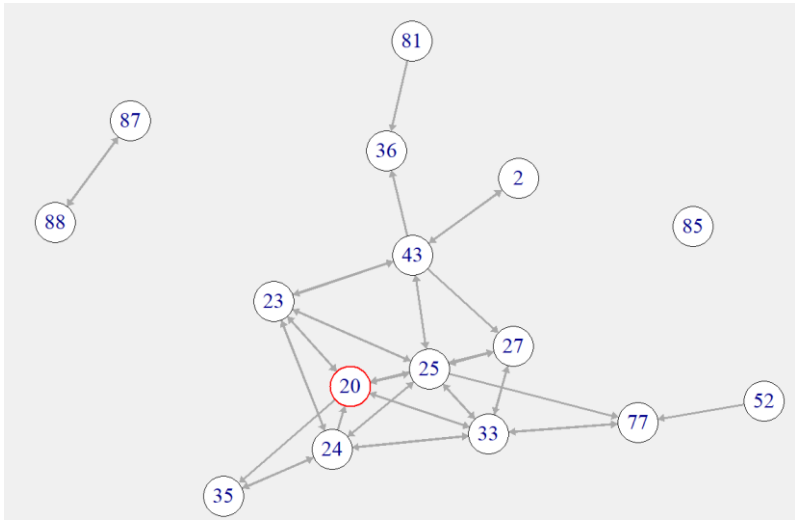
Figure 16 Potential knowledge network for the Sauda labour market region.

Source: own calculations based on data from Statistics Norway (2017b).

5 Conclusions

5.1 Smart Specialisation in the context of prioritized industries

Policymakers can enrich their information for industrial restructuring decision by using, at the same time, different data sources. We argue that the increasing availability of "big data", concerning also labour flows and international transactions, will be able to generate new information relevant for policy-making. The challenge will be to establish new adequate procedures for translating automatically the increasing amount of data into valuable information. Especially in the face of the current social and environmental challenges, which will require fast local actions in connection with large-scale phenomena, the possibility of a fast "zoom-in" on the economic potential of regions can acquire importance.

The approach laid out in this study demonstrates how inter-regional labour flows can be used to map relatedness between regions. It is informed by lessons from the regional branching and related variety literature, notably:

- that economic growth in given industries hinges on the ability to promote the production, distribution and use of knowledge within and across regional economies (Antonelli, Patrucco, & Quatraro, 2011);
- that the potential for regional growth in the prioritized industries depends to a significant degree on the number of industries that are technologically related (Frenken, Van Oort, & Verburg, 2007);
- that industrial diversification depends on the accumulation of technological competences at the regional level (Tanner, 2014);
- and that extra-regional knowledge may be important for targeting regions where there is a requisite level of relatedness between originators and recipients (Boschma & Iammarino, 2009).

The exercise builds a framework for empirical analysis of economic restructuring on this groundwork. Using Norwegian data, the approach identifies areas where there are higher (lower) potential for (re)combination of extra-regional knowledge in prioritized areas. The ultimate aim of this exercise is to demonstrate

how this type of analysis can be used to inform policy as it seeks to prioritize green restructuring.

The evidence can help innovation policy as it attempts to prioritize green industries and make them economically viable. To aid in this endeavour, this section follows Boschma and Gianelle (2014) who illustrate how regional branching can be used to support smart specialisation policy. Basic concepts and caveats of the Smart Specialisation approach are presented in the current context before we mention a number of potential extensions.

The approach demonstrated above is able to identify activities that may be stimulated so as to connect them to technologically related industries in other regions. It may therefore be relevant to inform policy interventions within the 'smart specialisation' framework[7]. 'Smart specialisation' in general involves a public policy focus on domains that "complement the country's other productive assets to create future domestic capability and interregional comparative advantage" (Foray et al., 2009). This entails prioritising public investments in knowledge-based assets via a combination of bottom-up and top-down processes at the regional level.

Following recommendations in Foray, Mowery, and Nelson (2012), the framework is designed to focus public investments on particular activities so as to enhance the strengths of the capabilities already found there. The overall goal is to promote "structural change in the economy through investments in knowledge-based assets and better governance in STI policy making" (OECD, 2013, p. 14).

As the OECD (2013) indicates, the smart specialisation framework assumes that the public policy frame has at its disposal three types of capabilities, namely:

- the capacity to identify local strengths;
- the ability to align policy actions and to build critical mass; and
- the ability of regions to develop a vision and implement the strategy.

It further emphasises the importance of a 'diagnostic system' to analyse the match between the technological and the economic performance.

The mapping exercise identifies activities where there are potential areas for recombination of complementary assets that could be used to encourage regions to branch into new activities. The approach demonstrates a promising way to use data resources available in Norway as well as in other European countries, specifically using firm-linked trade-data (to help map embodied capabilities) and linked employment data (to help map technological capacities) to create a foundation for such a "diagnostic system". The final example we have shown, about a fast "semi-

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[7] as set out in EU's white paper (now enshrined in the EU 2020 Agenda): (European Commission, 2009).

automatic" selection of candidate regions for a photovoltaic-industry policy, indicates the potential of international trade transaction data as a signal of input-output relations in an emerging policy-relevant sector. We want to emphasize that, through our data, we are able to grasp information about current value and availability of both natural resources and intermediate goods, describing economic elements which go beyond the technological relations among sectors. Not only international transactions show what firms need: they also show the financial burden of acquiring what firms need. When evaluating the economic feasibility of an industrial policy, this information may become extremely valuable.

5.2 Caveats

In applying the Smart Specialisation to this area, a number of caveats should be observed. In our application, policy has already prioritized the technological areas according to environmental objectives. Caution should be used here. The Smart Specialisation approach is very clear about the potential risk that policymakers face if they try to develop growth paths into specified activities and industries. In general, smart specialisation insists that policymakers resist the urge to try to 'pick winners'.

However, the promotion of environmental technologies in addressing a wider 'societal challenge' provides a separate policy issue (Foray et al., 2009; Mowery et al., 2010). It is not restricted to a response to "market failure". Instead, the government starts from a set of priorities and the question is how to best focus resources on the achievement of specific objectives in support of policy goals. Policymakers need to understand mechanisms that may shape the new growth paths into these technologies based on existing activity and assets, and they need a way to diagnose points in the system where there are apparent strengths or weaknesses. A diagnostic system of the type demonstrated above may help to monitor where knowledge flows are helping to promote policy-relevant sectors, and also to understand where policy-relevant sectors can contribute best to knowledge flows.

The Norwegian case is one in which public policy has a long track-record of investing in innovative areas of the 'green economy' despite the dominant position of the petroleum industry. The question is how to best combine these efforts with that to promote innovation. The approach above, using labour flows, illustrates one way to gauge the diversification into different environmentally-oriented activities.

We bear in mind that a quantitative empirical method cannot alone provide an ultimate answer about how to purse a policy goal, since qualitative considerations and theoretical models are essential for a deep understanding of sectoral co-evo-

lution. We advocate the use of a quantitative empirical method to restrict the researcher's attention to a smaller set of sectors and regions, so that a smaller amount of costly time and efforts would be needed by a complementary focused research.

A difficulty we encounter, when developing a methodology based on a sectoral classification, lies in the relation between manufacturing and service activities. Services retain a strong importance in the regional economies not only through their direct employment weight and value creation, but also by supporting the manufacturing activities in the region. Such support can occur by means of labourers operating service activities while employed by firms mainly devoted to manufacturing. As a consequence, there is a bias in our inference of sectoral skill-relatedness among sectors: some labour flows between manufacturing sectors could be due to the movement across firms of employees performing service activities, and thus would not witness a particular skill relatedness among manufacturing sectors.

Defining the border of a region, from a socio-economic perspective, also remains a difficult task. In our examples, we have used the borders of labour market areas to bound local knowledge flows, but knowledge can of course spill over into other regions. A possible way to cope with such difficulty is introducing, in the automatic procedures for data analysis, also elements of spatial econometrics, for instance to allow for some form of spatial dependence in the regional knowledge base.

Similarly, better ways should be found to redefine, for the purposes of the analysis, the borders between good categories. For each good under consideration in industrial policy planning, whether an input or an output for the industrial sector of interest, the level of category aggregation should be under exam. When using international trade data, a proper reflection should precede choosing the appropriate number of digit in the good's CPA or tariff code, and/or grouping together all goods that could fulfil the same function in the value chain.

5.3   Potential extensions and further research

There are several possible refinements in the current set up. The knowledge flows can be enriched by a better knowledge of the research and innovation patterns of the industries in which complementary assets are identified. R&D activity, innovation intensity and use of intellectual property rights can be associated with the different activities to better understand the types of employment flows and how they link with the innovation intensity of the different activities. A promising data source here is the link between the employment data and the R&D surveys connected to the Community Innovation Survey. Moreover, the intersection between

international trade data and regionalized patent activities in related technology fields constitutes a promising line of study. Patent applications in a technological area can be seen as indicative of ongoing RD&I activities that have a presumptive commercial value. Studying patent activities connected to a policy-relevant technology thus represents one important avenue for assessing the regional potential in an industrial sector.

Additional data about the location of firms (and of plants belonging to firms) could provide information about the inputs available to a particular region even when not produced in the region. A suggestion for further research is then: in order to choose where to implement an industrial policy, it is worth considering not only where to create local value chains, but also where to connect to existing international value chains. In other words, it would be useful to identify a set of regions that are internationally connected to a strategic input, because of the existing presence of local importers. More in general, the existing international trade in a strategic input, if associated to a particular region, could qualify the same region as a target location for a national industrial policy.

Finally, additional input-output considerations could be drawn on the basis of regional-level maps of natural resources. For instance, maps built on the basis of previous studies about forest localization and wind strength could be used as additional "layers" for the input-output restriction, to suggest local supply chains in respectively wood-based and wind-power industries.

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List of tables

List of figures