Empirical Research Avenues for Regional Policy Elaboration

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Preface

This Working Paper 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 Filippo Bontadini, Tom Brökel, Rikard Eriksson, Jens Grøgaard, Sverre Herstad, Trond Løyning, Svein Olav Nås, Angelo Secchi, Bram Timmermans and all the participants to the NIFU workshop on Industrial Dynamics, September 2017, for useful comments and suggestions, and the Research Council of Norway 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, December 2017

Espen Solberg
Head of Research

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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.

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. In addition, the approach can be fruitfully extended to include other types of flows. A promising avenue of study is to use trade patterns and their evolution to specialisation and economic restructuring at the regional level. Trade literature provides an important avenue for understanding economic restructuring that has not yet been sufficiently researched. 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 ‘sociatal challenges’ such as climate change (see Mowery, Nelson and Martin, 2010; Foray, David and Hall, 2009). 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.

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.

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 renewable energy systems and the circular bioeconomy. The paper develops an approach that can help direct policy attention as it pursues this aim. The paper uses 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’.

The paper is organized in the following way. The second section takes stock of green restructuring in Norway by focusing on specific (sub)sectors; the third section surveys the empirically oriented literature of economic geography to introduce policy concerns and approaches to address these; the paper’s approach is presented in the fourth section to illustrate how labour flows can be used identify potential for regional diversification into green industries. The final section considers how this approach can be used within the smart specialisation policy framework and it discusses some extensions.

[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.

2 Motivation: green restructuring of the economy

2.1 General considerations

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 and O'Neill, 2014, p. 206). In this scoping paper, we specifically draw the attention on some key sectors of the Norwegian economy: renewable energy, sustainable road transport solutions, and urban waste management.

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 et al. (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.).

In the following we will explain some of the peculiarities of the Norwegian economy and will give some comments from the international discourse on similar issues.

2.2 Renewable energy

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 and 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 and 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, Rese and Baier, 2016, p. 9).

2.3 Offshore wind

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 and 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 et al., 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 and 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 and 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 and 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 and 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, Lecca and Musso (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.

2.4 Solar photovoltaic industry

Norway has a long tradition starting over a century ago for exploiting hydropower for processing industry, such as for processing of different metals such as aluminium, producing fertilizers and refining solar silicon. These industries are mainly oriented towards the export market and not that much towards a domestic market, which is a parallel to the offshore wind industry.

The establishment of the solar photovoltaic industry has been a result of an interaction of the technological innovation system of the metallurgical silicon industry processing magnesium and silicon – here skills and materials were transferred through spin-offs and diversification, with the electrometallurgical industry sector in general – the sector contributed with more generic resources like finance, labour and infrastructure (Hanson, 2017, p. 11). Hanson's analysis has shown that both embodied resource flows in form of machines, equipment and infrastructure, and flows of disembodied resources in form of education, scientific and technical literature, and consultancy have contributed to the emergence of this industry (Hanson, 2017, p. 3).

An analysis of the regional distribution of the solar photovoltaic industry in Norway shows that the industry started in Eastern Norway, where the emerging industry profited from knowledge spillovers (collaboration and labour mobility) from different co-located incumbent process industries and the automobile industry Klitkou and Coenen, 2013.

In international studies on trade dynamics in the solar photovoltaic industry it was shown that there have been changes in the international trade patterns for solar photovoltaic technology (Algieri, Aquino and Succurro, 2011; Zhao, Yang and Zuo, 2017). During the *rapid growth stage* from 2005 to 2011 Europe, with large trade intensity, occupied the dominant role in the international trade. Economic incentives boosted consumer demand. Trade connections within the Asia-Pacific region were strengthened mainly due to cheap labour and resources, producer demand and geographical advantages (Zhao, Yang and Zuo, 2017). In the *stabilizing stage* from 2012 to 2015 global trade patterns changed dramatically. While trade intensity of European countries declined, China became the new international trade centre for solar PV, now also engaging more in deployment of solar PV in China (ibid.).

2.5 Organic waste management

In this scoping paper, we concentrate on organic waste streams, addressing sorting, collection and transport of waste streams and processing of organic waste streams. In Norway, the origin of these 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., 2016; Lausselet et al., 2017). 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 and Meibom, 2010; Uyarra and 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 were 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.

2.6 Sustainable road transport

In the road transportation sector, public policy has been much more oriented towards changes in the Norwegian society, but parts of these policies, especially related to the introduction of economic incentives for biofuels, have been rather unstable and unpredictable. Road transportation systems constitute a distributed and interrelated set of technologies, infrastructure and regulations. We can distinguish between: (a) the car engine or propulsion system in the choice of road vehicles; (b) the system of fuel production and (c) the related infrastructure: the filling stations, mechanics, car dealers, fuel producers, not to mention component development for fuel distribution and transportation.

Norwegian e-mobility policy has contributed successfully to a market uptake and an expansion of electric vehicles in Norway (Figenbaum et al., 2015). There has been a shifting focus from supporting the domestic electrical vehicle industry towards a broad range of policy instruments boosting the demand for battery electrical vehicles (BEVs) and supporting the installation of the necessary charging infrastructure. And the regional distribution of BEVs changed dramatically over the last ten years implying that also the distribution of charging infrastructure had to be developed accordingly. While at the start this was more a phenomenon for the capital of Oslo this is now distributed to many parts of the country. Today, Norway has the world highest number of electrical vehicles per capita. In the first quarter of 2017 there were about 100.000 BEVs registered as personal vehicles in Norway (Source: SSB).[2]

Policy interventions show a tendency of integrating supply-side (e.g. support of battery or hydrogen RD&D, technology procurement contracts, other support BEV producers, and later support car factories), demand side interventions (measures that promote adoption such as tax incentives, free parking, public procurement of BEVs, etc.) and infrastructure policy. The local attempts to jumpstart supply and demand while providing infrastructure and 'institutional embeddedness', such as in Oslo, have also played a role, especially when allied with other policies as is the case in Norway.

[2] https://www.ssb.no/transport-og-reiseliv/statistikker/bilreg/aar/2017-03-28

3 From data to information: reflections on the previous literature

3.1 The state of the region

A policy for regional restructuring must be based on knowledge about the capabilities embedded in the current economic composition of the region. If we think that the economic capabilities, in terms of technology, skills and natural resources, have a correspondence with the sectors which, in terms of firms and employees, compose the regional economy, then the sectoral composition of the region represents the ideal starting point for the policy-maker. 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 in each sector, as proxied, for instance, in terms of employment or turnover.

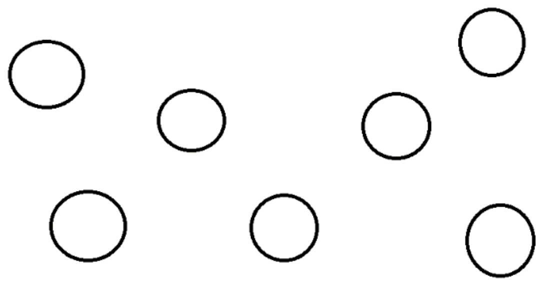

Figure 1: Economic sectors in a region.

A second reason to use the economic sectors as units of our regional analysis lies in the channels that the regional policy is going to utilize. If the policy instruments are going to affect different firms (incumbents or entrants), a first way to group the target firms is according to 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 ideal 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 foster the production of photovoltaic panels implies a fine sectoral disaggregation after which the regional current status should be examined.

Once the economic activities in the region have been labelled according to the economic sectors to which they pertain, and have thus been grouped in different subsets (the circles in Figure 1), each subset can be seen as a node in a network, where two nodes are connected if the knowledge exchange between the two corresponding sectors can potentially bear fruit in terms of innovation and growth. 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, 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 the utilization of 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.

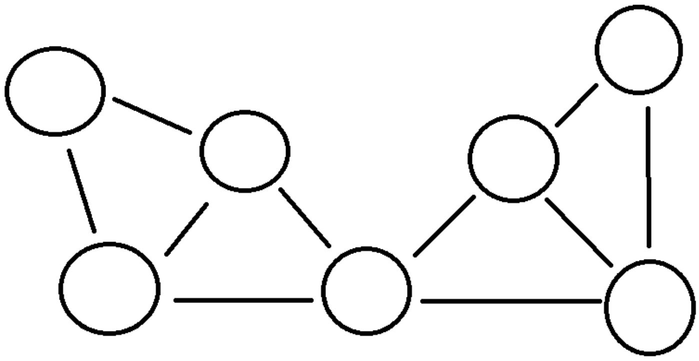

Figure 2: Potential knowledge flows across sectors.

Once the connections are built, the vision of the potential knowledge flows across the economic sectors in the region allows a first assessment on 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 the knowledge flowing throughout the economy.

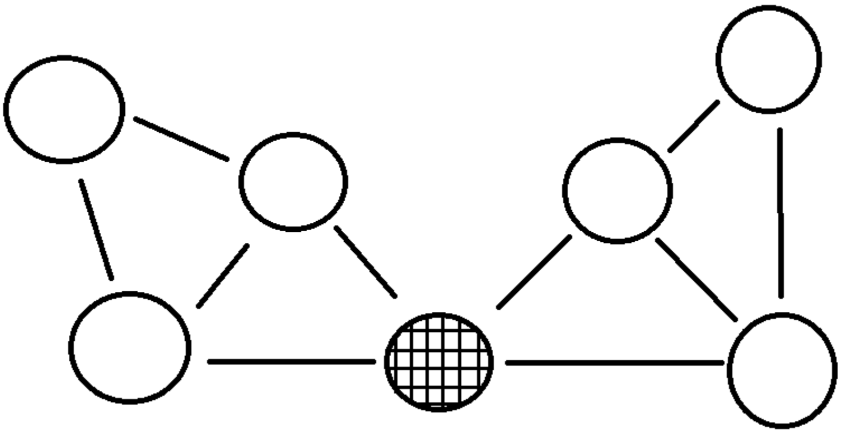

Figure 3: Strategic position.

The checkered 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 “checkered” sector is not sufficiently represented yet in the region, the regional policy could incentivate the growth of that sector into a hub for future knowledge exchanges in the region.

3.2 Policy goals and industrial dynamics

A question addressed at a regional policymaker could 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 give an equal, if not higher, weight to contribution of that sector to the 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: 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 checkered node appears as a destination of flows instead of an origin.

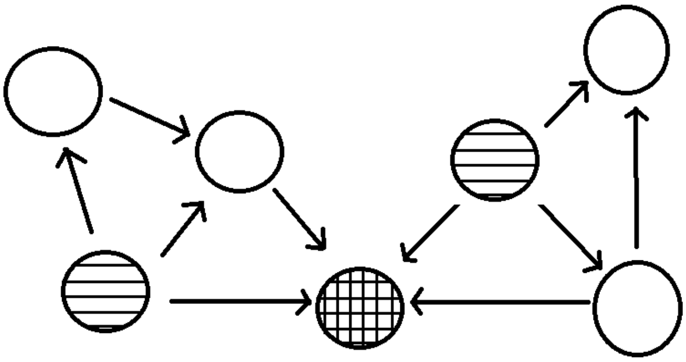

Figure 4: Directed network.

Recent empirical works on regional innovation systems (see Fitjar and Timmermans, 2016; Herstad and Sandven, 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 economies would force policymakers to refine the boundaries of their goals, since a sector in a strategic position for its own growth may not appear anymore 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” economic sectors instead of the “checkered” economic sector, whose position seemed to be strategic within the undirected network of Figure 3, but not anymore in the in 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 advices. 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 the 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 is going to 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 a longer run, also sectors which are far away in the regional network are going to be negatively influenced.

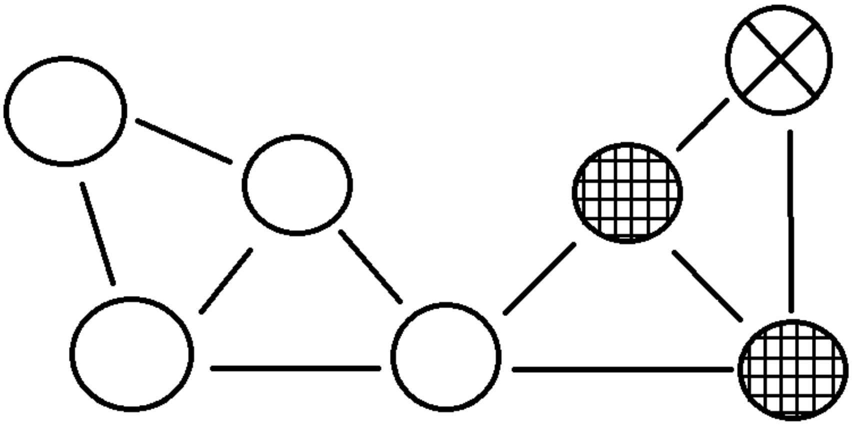

Figure 5: Percolation.

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 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 and 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 “checkered” 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.

3.3 Factors of production and economic circularity

An additional reason for considering as strategic the checkered nodes in Figure 5 lies outside the context of knowledge dynamics, and connects instead 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 fast reallocation of dismissed workers. As a consequence, the observation of past heavy flows of employees between the currently declining sector and the checkered nodes would also suggest that the “checkered” nodes in Figure 5 could easily absorb the workers dismissed from the declining sector. In case the checkered sectors are expanding, they could temporarily gain from the decline of the neighbouring sector by attracting the brightest employees. The regional authorities should thus elaborate a strategy to best complement the labour force, become potentially available to the checkered sectors, with policy-driven fixed and financial capital.

Moreover, the authorities must 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 force 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 from the suppliers of the suppliers, and from all the other actors situated upstream along the supply chain. Input-output analysis should 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 some 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 and Los, 2010; Montresor and Marzetti, 2009).

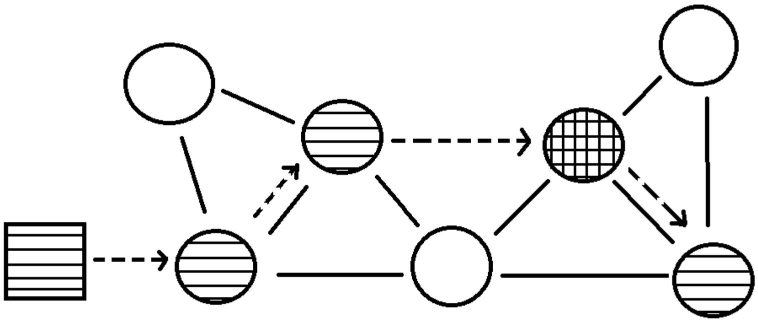

Figure 6: Input-output relations.

Input-output tables are often built at 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 and Bruggeman, 2017). If the task of the researcher is assessing 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 must be made in this respect. 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 the extraction of natural resources require some inputs, while the waste from final consumers can also become itself 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 more the direct links of the target sector 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 should build a “bill of goods” (see e.g. Bess and Ambargis, 2011) for the target sector, in the sense that technical experts should assess what would be the direct inputs needed for the new technology, and reshape accordingly the direct links in the input-output network (i.e. the dashed lines around the checkered node in Figure 6).

Thirdly, the downstream effects of the policy should not be underestimated. Innovation in the target sector translates in 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 which do not belong to the target sector but 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. Pavitt, 1984; Castellacci, 2008).

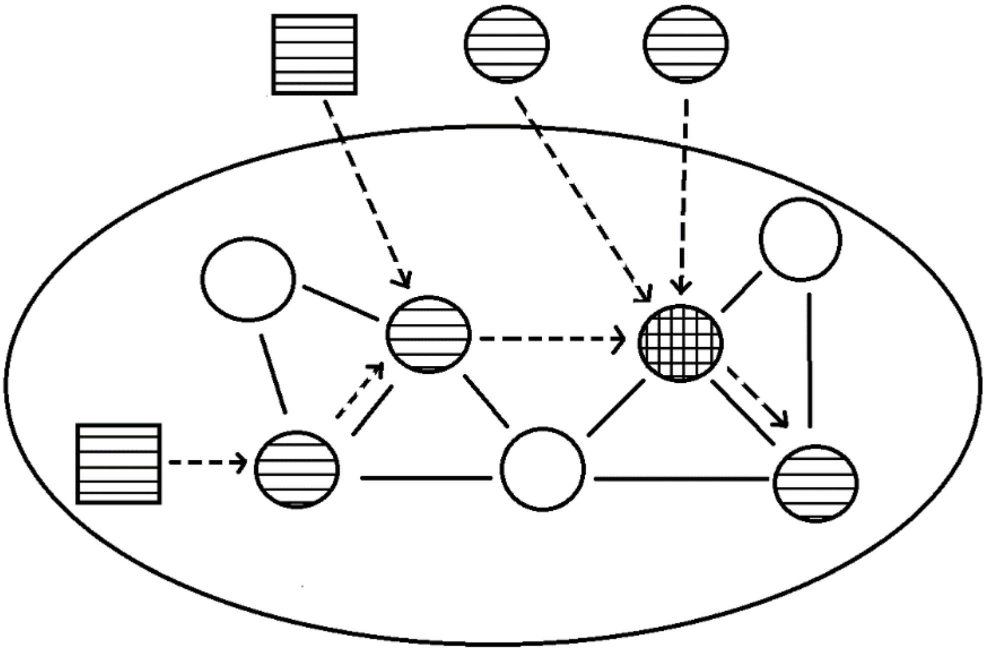

Figure 7: Interregional and international trade.

3.4 The region as an open economy

Input-output tables are usually built from primary data referring to money flows, rather than to goods quantities. 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 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. Having more details about the chain, in terms of additional information about which value has been 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 of overwhelming importance (North, 1955; Thirlwall, 1980).

For the purpose of empirical analyses, it is convenient to subclassify interregional transactions as between, respectively, international transactions and interregional, but not international, transactions. 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 nation-wide composition (Dunn, 1960). However, a traditional shift-share analysis is insufficient to assess and predict regional competitiveness when the reference markets are supernational (Fotopoulos, Kallioras and Petrakos, 2010; Chiang, 2011).

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 et al., 2012), opens many new opportunities for regional analysis. On the one hand, it brings 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, looking at the type of inputs that each region is searching internationally, in order to allow the current output in terms of goods and services, concurs to suggest the other types of outputs that the region could potentially have. Not only the existing trade channels could 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 and 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 (Mody and Yilmaz, 2002; Barba Navaretti, Galeotti and Mattozzi, 2004).

International trade data 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 2-digit level. Such limitation affects also the newly developed "world input-output tables", which describe connections among 2-digit sectors located in different countries, and thus allow to derive network properties of international macroeconomic flows (Contreras and Fagiolo, 2014; Cerina et al., 2015), but can hardly provide scientific support for fine-grained industrial policies. On the other hand, databases like the United Nations COMTRADE, used for instance by Hausmann, Hwang and Rodrik (2007) and Hidalgo and Hausmann (2009) to understand the evolution of a country's export mix, are disaggregated from the sectoral point of view (trade flows between countries are described at a 6-digit product disaggregation) but still keep a national level of geographic aggregation, preventing the researcher from a full view of the regional embedding of the export impulse. 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).

4 Two empirical examples

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

In order to show how the suggestions above may initiate new trends of empirical analysis, we now provide two empirical examples of how both knowledge flow analyses and input-output considerations may be combined to help the decision-making processes of policy-makers.

We used the linked employee-employer data from Statistics Norway (2017). The data at the individual employee level cover all persons in Norway between the age of 15 and the age of 75, and they have the firm in which the employee works as a variable, identified by a unique firm number. 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 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 have registered all employees who moved from one firm to another from one year to the next, i.e. from 2008 to 2009, from 2009 to 2010, and so on, and have cross-classified them by the industry they left in the former year and the industry they entered in the latter year. We have here included movements within the same industry. Then all these inter and intra industry flows for each of these six consecutive pairs of years have been added 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 we have computed the labour flows both at the 2-, 3- and 4-digit Nace levels. 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. Firms are here defined at the individual plant or establishment level, not 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.

We have only included employees between 18 and 65 years of age, who worked at least 20 hours a week. The observed flows of persons between industries have been 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

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 and Timmermans, 2016).

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 is statistically significant, we have used the *adjusted residuals* test for each cell, as suggested by Alan Agresti (see p. 31 in Agresti, 1996). These 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 here 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.

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

We have computed the distribution of employees across industries in all regions in Norway for year 2014. For the definition of regions, we have used 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 use first 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 have calculated 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 have constructed a ratio between observed and expected, and we have normalised 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.

4.3 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 production of energy. At the same time, the supply chain should be partially localized, to experience multiplication effects in the same region, and potential upstream, complementary and downstream sectors should thus be already present in the region. 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.

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 4.2, 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 4.2, 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 his position would be if it were becoming overrepresented following our policy.

The network connections among the nodes, that is 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 4.1. In particular, we consider two sectors *i* and *j* as connected if (see definitions in Section 4.1): $Rationorm_{ij} > 0.25$; $Adjres_{ij} > 3$; expected frequency > 10.

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 get through the input-ouput 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 an important role in channelling knowledge throughout the whole region.

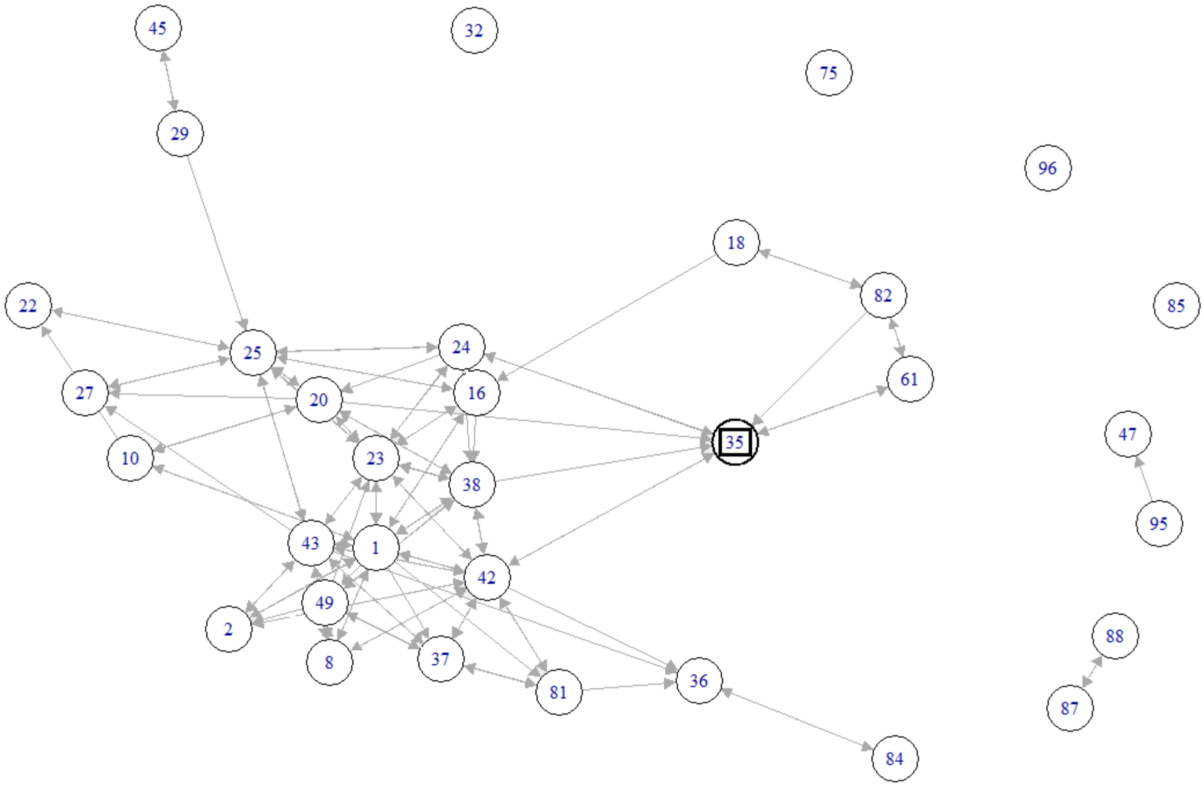

Figure 8: Kongsvinger potential knowledge network.
Source: own calculations based on data from Statistics Norway (2017).

In Gjøvik, the target sector “Electricity, gas, steam and air conditioning supply” could still be a 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 reproduction of recorded media”) and 82 (“Office administrative, office support and other business support activities”) were connecting “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.

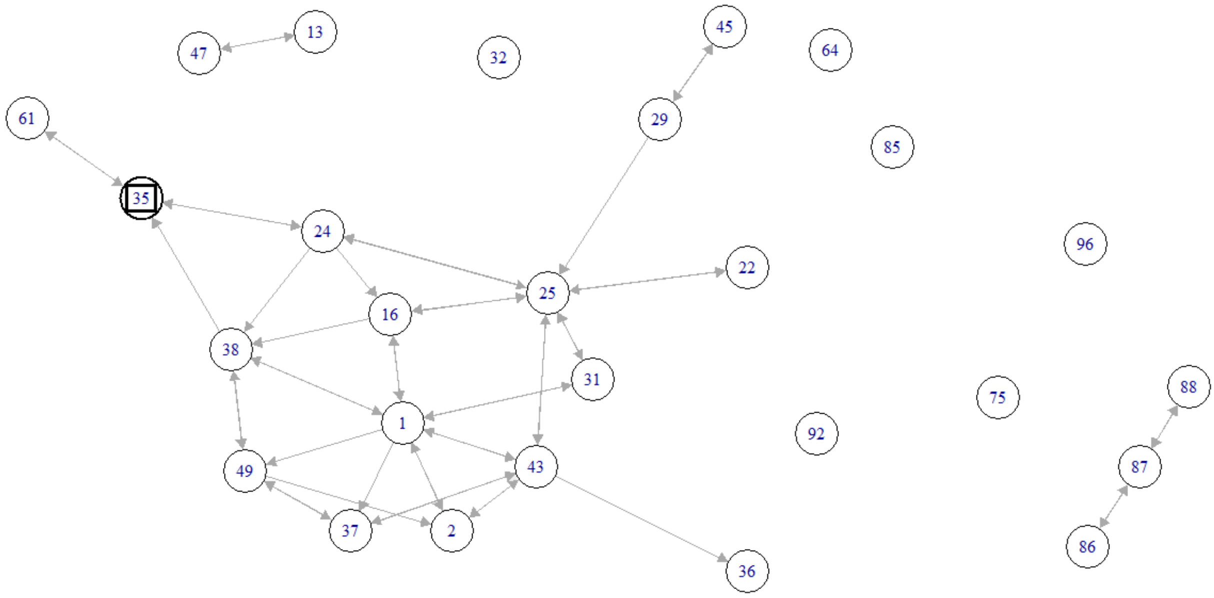

Figure 9: Gjøvik potential knowledge network.
Source: own calculations based on data from Statistics Norway (2017).

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.

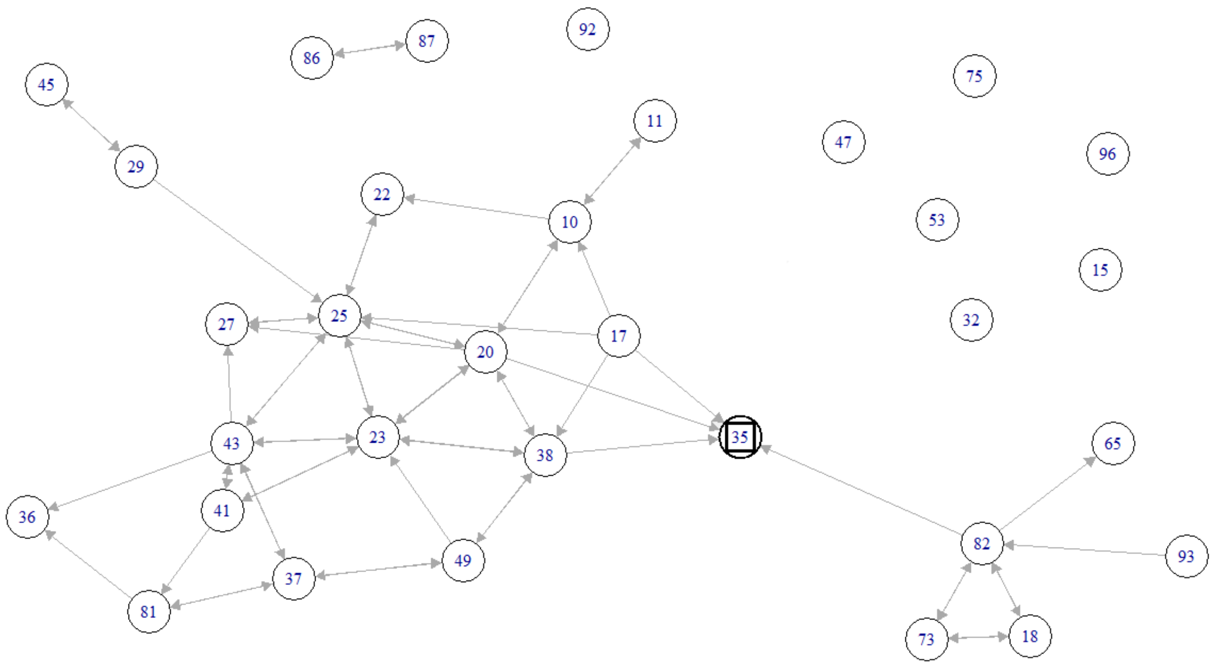

Figure 10: Fredrikstad/Sarpsborg potential knowledge network.
Source: own calculations based on data from Statistics Norway (2017).

4.4 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-ouput restriction and the knowledge network analysis are applied on 4-digit economic 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 utlization 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 4.2, 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” (2-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 as an interesting candidate for the production of wind power: let’s see why.

Molde gets through the input-ouput restriction by already having 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”).

As shown in Figure 11, Molde could 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.

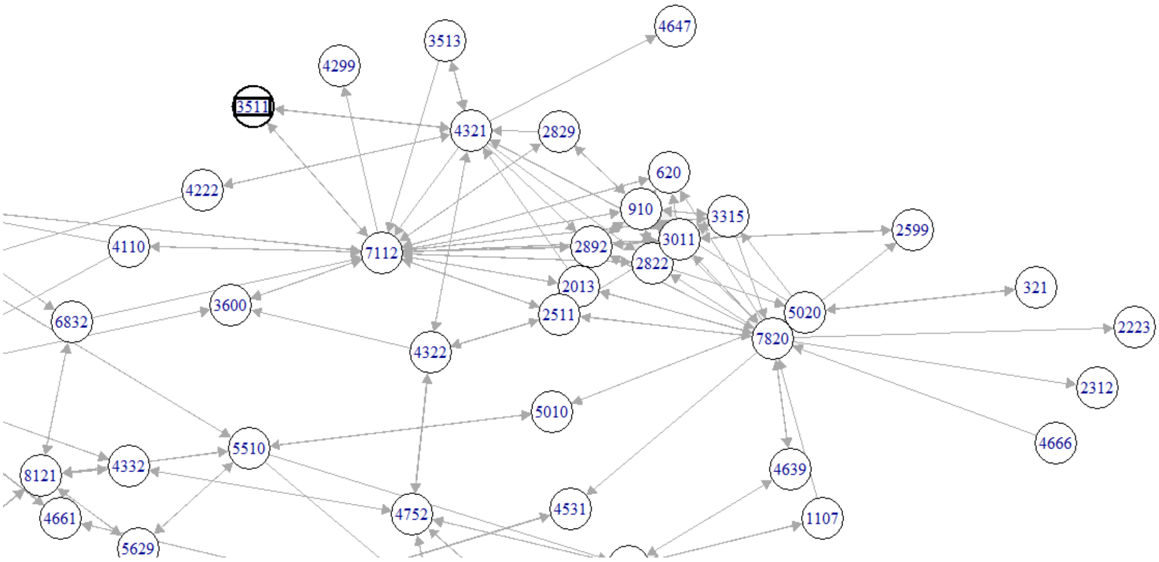

Figure 11: Molde potential knowledge network (detail).
Source: own calculations based on data from Statistics Norway (2017).

In Arendal, instead, 7112 ("Engineering activities and related technical consultancy") is not currently well represented, and therefore a policy devoted toward 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 happens in spite of Arendal satisfying 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.

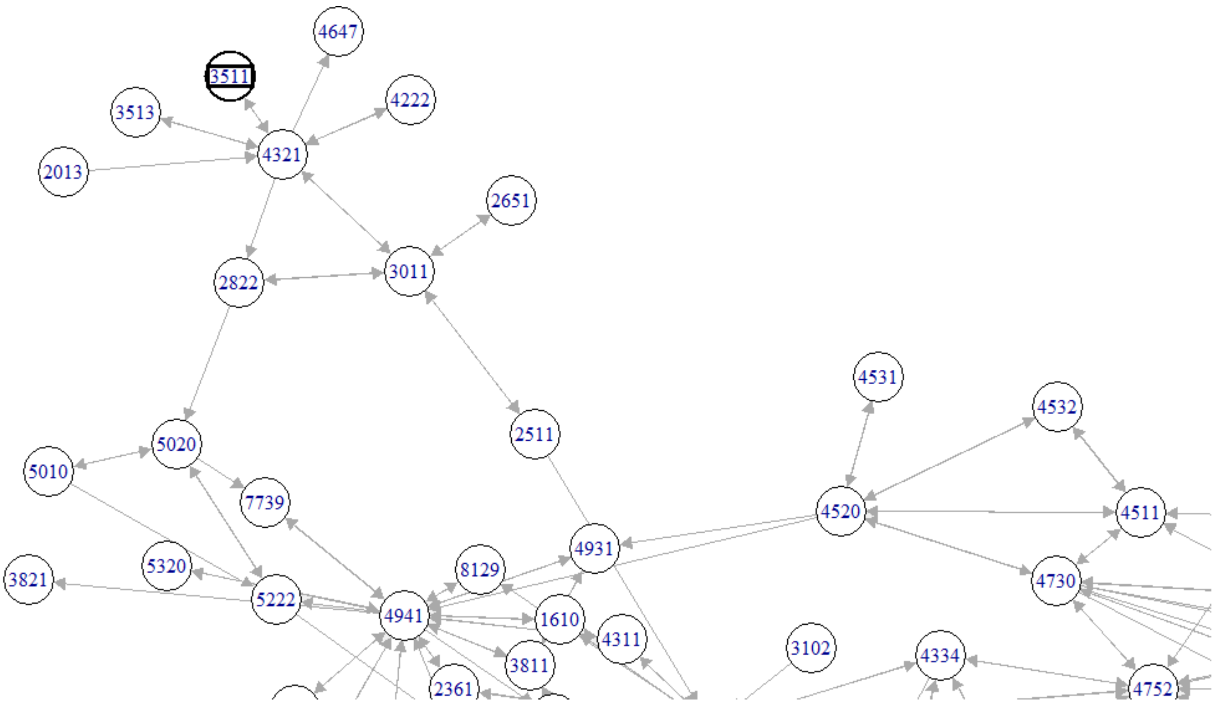

Figure 12: Arendal potential knowledge network (detail).
Source: own calculations based on data from Statistics Norway (2017).

5 Conclusions

5.1 Smart Specialisation in the context of prioritized industries

The approach laid out above 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 and 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 and 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 and 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 Norwegian 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[3]. 'Smart specialisation' in general involves a public policy focus on domains that, "complement the country's other productive assets to create

[3] as set out in EU's white paper (now enshrined in the EU 2020 Agenda): European Commission (2009). Knowledge for Growth: Prospects for Science, Technology and Innovation; Selected Papers from Research Commissioner Janez Potočnik's Expert Group, Publications Office of the European Union.

future domestic capability and interregional comparative advantage" (Foray, David and Hall, 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, 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 section above illustrates how the approach can be used to 'identify local strengths' as they relate to the restructuring processes at issue here and can be used to inform policy "capability failures", "directionality failure" and "demand-articulation failure".

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, David and Hall, 2009; Mowery, Nelson and Martin, 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 govern both to monitor where knowledge flows are helping to promote policy-relevant sectors.

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.

5.3 Potential extensions and further research

The 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.

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. The role of knowledge flows that involve multinational enterprises may also be useful to understand the mechanisms for how knowledge flows may lead to growth paths. A promising data source here is the link between the employment data and the R&D surveys connected to the Community Innovation Survey.

In addition, the approach can be fruitfully extended to include other types of flows. A promising direction of study is to use international trade patterns and their relation to specialisation and economic restructuring at the regional level. The trade literature provides an important avenue for understanding economic restructuring, an avenue which has not yet been sufficiently exploited. In general, the literature indicates that trade patterns engender a range of factor endowments, from traditional tangible measures of “capital” (as in the Heckscher-Ohlin theory) to “intangible” factors like skills and institutions, which are part of a location's endowment. The upshot is that trade involves the exchange not just of capital goods, services and commodities, but also the exchange of the technological capabilities and the know-how that are associated with them.

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, sun light availability and wind strength could be used as additional “layers” for the input-output restriction, to suggest local supply chains in respectively wood-based, photovoltaic and wind-power industries.

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