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Innovations and renewables in the Nordic countries: A panel causality approach

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ABSTRACT

Most studies on the relationship between technological innovations and renewable energy consumption have focused on the role of technological innovations in the link between energy consumption and economic growth, with no deep analysis of direct causality between renewable energy and technological innovation. This study examines the direct causal relationship between technological innovation and renewables in the four Nordic countries by using the bootstrap panel Granger causality approach that accounts for both cross-sectional dependence and slope heterogeneity across countries. The results show a unidirectional causality running from technological innovations to renewable energy in Denmark and Norway, and a unidirectional causality running from renewables to innovations in Sweden and Finland. The main reasons of the divergent results could be energy mix, role of nuclear energy, the different economic structures, and role of policies. The policy implications are that technological innovations play an effective role in renewable energy consumption and renewable energy itself spurs innovations. Thus, speeding up the transition to renewable energy requires investment in technological innovations.

1. Introduction

The global human population continues to grow and countries are continuing to develop, causing significant increases in the demand for energy. At the current rate of increasing energy use, energy demand is expected to increase 65% from 2004 levels by 2030 [12]. However, the majority of energy currently used globally is obtained from non-renewable sources [11,12]. The increasing magnitude of global energy consumption and its rapid growth have important environmental implications.

Since the oil crisis of the early 1970s, the four Nordic countries (Denmark, Finland, Norway, and Sweden) have invested heavily in the search for alternative energy sources. Measures to decrease the use of oil have proceeded smoothly.[1] In 1970, oil accounted for more than 70% of energy supplies in the Nordic countries; by 2012, the figure was around 20%, mainly due to the declining use of oil for residential heating. The most part of electricity in the Nordic countries comes from nuclear power and hydroelectric power, cogeneration from combined heat and power, and wind. In the transition to a sustainable society, wave power may be an important technology in the future, but it is still relatively undeveloped. Thus, the Nordic countries attempt to promote efficient and sustainable energy use and a cost-effective energy supply that would facilitate the transition to an ecologically sustainable society.

However, the growing concern about environmental issues has spurred the importance of renewable energy. It is widely accepted that renewable energy is virtually carbon free energy sources that can serve as a potential solution to both energy security and climate change problems. The Nordic countries have made a significant investment in renewable energy sources and are now regarded as the leaders in the area.

The relative importance of renewable energy in gross inland consumption is relatively high in Denmark (24.2%), Finland (29.2%), Sweden (34.8%), and Norway (37.4%). The Nordic electricity production is two thirds renewable. This is because of the large amount of hydropower in these countries (especially Norway and Sweden) but also to growing sources of other renewable energies. Biomass is burned in combined heat and power plants across Finland and Sweden, while Denmark has the highest share of wind power in the world. In addition to renewable energy, nuclear power in Sweden and Finland means that the region's electricity is mostly carbon free.

Most studies on the relationship between technological innovations and renewable energy consumption have focused on the role of technological innovations in the link between energy consumption and economic growth, with no deep analysis of direct causality between renewable energy and technological innovation. Examples are [3,5,7,14,16–18]. Generally speaking, the results show that

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[1] All data in this section comes from EuroStat and International Energy Agency (IEA).

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technological innovation plays a significant role in the clean energy-growth nexus. Their results are in line with the applicability of the endogenous growth theory on the energy sector.

None of the above-mentioned studies investigates direct causality between innovations and renewables. Thus, the aim of this study is to examine the direct causal linkage between the renewable energy consumption and technological innovations. As energy systems are foundations for our civil society, this paper examines energy sector from an innovation and technology perspective. Furthermore, Ref. [4] suggests a co-evolutionary approach and argues that socio-technical and techno-economic change for sustainability can be analyzed through the coevolution of ecosystems, technologies, institutions, business strategies and user practices.[2] These elements of the system co-evolve because they have significant causal impact on each other's ability to persist. However, the study covers the period 1975–2012 and employs the bootstrap panel Granger causality approach that accounts for both cross-sectional dependence and slope heterogeneity across countries. To the best of the author's knowledge, this is the first study to investigate the direct causal linkage between the series in the Nordic countries.

The reminder of the paper is organized as follows. Section 2 presents some stylized facts about energy sector in the Nordic countries, Section 3 presents the data and methodology. Section 4 provides the empirical findings. The last section offers conclusions.

2. Overview of the energy sector in the Nordic countries

Over a third of the Nordic region's energy supply comes from renewable sources.[3] The largest of these is biomass and waste which are used to produce electricity, heat and transport fuels. Renewable electricity in the region is also taken from hydropower as well as growing share of wind power. With nuclear power in Sweden and Finland, over half of the region's energy is carbon free. Oil is still the largest single energy source, because of its central role as a transport fuel. The 1970s oil crises has caused a move away from oil and towards alternative energy sources in power generation which is evident in an increase in the use of nuclear energy in Sweden and Finland, as well as in a rise in the use of coal in Finland and Denmark.

During the past decades, it has been a significant growth in renewable energy sources such as biomass and wind while the amount of hydroelectric power produced in the Nordic region has only experienced minor growth. Countries characterized with significant heavy industries will typically have a higher energy intensity than countries earning GDP primarily from service sectors. Denmark has the lowest ratio which means that there exists energy efficiency in production process and there are no energy intensive industries. By comparison, Finland, Sweden, and Norway have higher energy intensities due to manufacturing industries.

Countries dominated by primary and secondary sectors, such as Denmark and Norway, have steadily decreased their energy intensities since 1990 and Sweden and Finland have also followed this trend. Even with respect to fossil-fuel intensity, the Nordic countries are well ahead of the other countries in their fossil-fuel efficiency because of their high utilization of renewable energy. Fig. 1 indicates time plot of renewable energy consumption in terms of thousand tone in the Nordic countries from 1975 to 2012. A total of 35% of the energy supply and 65% of

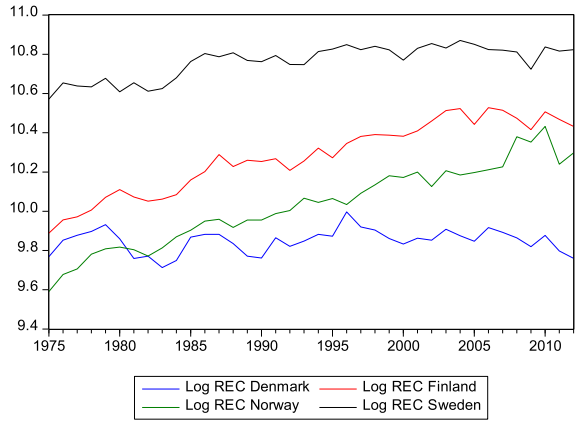

Fig. 1. Renewable energy consumption in the Nordic countries (1975–2012).

electricity production in the Nordic countries is renewable. This stems from the large amount of hydropower in Norway, and Sweden, but also to growing sources of other renewable sources. Biomass is burned in combined heat and power plants across Finland and Sweden, while Denmark has significant wind power. Beside renewable sources, nuclear power in Sweden and Finland means that the region's electricity is 85% carbon free. At almost two thirds, the Nordic region has one of the highest shares of renewable electricity consumption in the world and all four Nordic countries stand above the EU27 average, with Norway having close to 100% renewable electricity consumption.

The commitment of the Nordic countries for renewable energy may be due to the development of specific policy instruments to increase renewable energy production. Carbon taxes (Norway), feed-in tariffs (Denmark), investment grants (Finland), and electricity certificates (Sweden), are examples of specific policy instruments. Another reason for this development is the support for research and development (R&D) of new energy technologies. All the Nordic countries except Norway (spending 1.7% of GDP) spend more on R&D than EU average of 2.0%. However, if the Norwegian R&D expenses were calculated per capita, spending would be higher due to Norway's extraordinarily high GDP. While R&D expenses in EU27 have indicated an unchanged proportion of GDP since the mid-1990s, the R&D expenses of the Nordic countries have typically increased. Fig. 2 shows time plots of real R&D spending on energy sector in the Nordic countries from 1975 to 2012.

Generally speaking, the Nordic countries have achieved significant progress in the use of renewable sources of energy during the last two decades. On average, the Nordic countries create electricity from renewable sources at four times the level of the OECD countries although there are considerable variations among countries mainly as a result of the availability of natural resources. Norway almost produces their electricity from renewable energy sources and hydropower stands for almost 100% of all the electricity generation from renewable, while Denmark produces approximately 30% of its electricity from renewable sources of which approximately 64% is generated from wind power with the rest coming from solid biomass and municipal waste. In Finland and Sweden biomass and hydropower are the main sources of renewable energy, which combined stand for approximately 35.5% in Finland and 55% in Sweden of the total generation of electrical power. Hydropower in Sweden stands for approximately 84.6% of the total electric power generated from renewable sources while in Finland this figure is approximately 58%.

However, the Nordic countries stand for more than 30% of the world's market in the production of wind energy technology. Innovation in bio-energy is also strong with a share of almost 30% of all biomass-based generation of heat and power in the industrialized world and around 10% of the total scientific knowledge production. Energy innovation is a very important economic activity in the Nordic countries assuming approximately 6% of total revenues and employment in

[2] A co-evolutionary framework presents the 'institutions' of civil society as critical elements in the development of energy systems. It is based on approaches to understanding socio-technical systems change, evolutionary economic analysis of the role of institutions, and historical analysis of industrial change. In this case, physical energy infrastructure co-evolves with socio-economic institutions, regulatory agencies, incumbent actors and social norms. Co-evolutionary approach is useful because it enables an integrated analysis of the human, environmental and technical elements that produce socio-technical systems.

[3] The data in this section comes from International Energy Agency (IEA), Nordic Energy Research, and Nordic Center for Spatial Development.