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The importance of transnational impacts of climate change in a power market

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ABSTRACT

We contribute to the discussion on transnational impacts of climate change by analysing the potential cross-border impacts climate change driven changes in the hydropower potential. We analyse this in the context of the Nordic countries where Norway and Sweden are likely to gain hydropower potential and Finland is likely to experience transnational impacts. We use an economic simulation model and a dynamic optimization model to study the impact of climate change to the production mix, the price of electricity, consumption of electricity and emissions from electricity production. We show that climate change might reduce prices through increased renewables supply, which decreases the profitability of power production. The changes in the inflow profile affect the hydropower profiles over the hydrological year such that the reduced inflow peak in the spring shifts the hydropower production from spring to autumn and winter. In addition the larger inflow increases the share of hydropower in production mix over the year. The emissions per consumed energy unit is going to be decreased because of the decreasing share of the thermal production in the system. However, increased hydropower production reduces prices which in turn increases the quantity demanded. This rebound effect somewhat dampens the emission reduction.

1. Introduction

Previous research has drawn attention to direct climate change impacts to energy systems (e.g. Mima and Criqui, 2015; Bartos and Chester, 2015; Panteli and Mancarella, 2015). Climate change can shape the environment where energy is produced and distributed and also affect the demand for energy (Ciscar and Dowling, 2014) as well as increase risks of extreme events to power infrastructure (Schaeffer et al., 2012). Adaptation to climate change is often considered to be a local activity, although it also has international dimensions. In a globalized world countries are not only affected by those impacts of climate change that develop directly within their borders. Various links to neighbouring countries and other parts of the world spread the impacts of climate change across borders. The resulting transnational impacts of climate change can be significant from an adaptation point of view and a new type of risks needs to be considered (Benzie et al., 2016).

The ‘indirect’ (Benzie, 2014) or ‘transnational’ (Benzie et al., 2016) impacts of climate change is a relatively novel concept in climate change adaptation literature. These kind of impacts have been recognized for long, but systematic assessments of transnational impacts are still at their infancy (Benzie et al., 2016). Thus Moser and Hart (2015) argue that ‘societal teleconnections’ unfold risks (and opportunities) that are not fully acknowledged in adaptation to climate change. Both Moser and Hart (2015) and Benzie et al. (2016) highlight economic activity as one of the potential transmitters of climate change impacts between even distant regions. Moser and Hart (2015) specifically single out energy systems as an important category for these kinds of impacts. Climate change can, for example, affect the supply of power in a region or cause extreme events which can affect the power markets and cause disruptions that lead to supply shocks even far from the directly affected area. The power markets and the technological infrastructure transmit the impacts of climate change. The promotion of renewable energy is a key objective in Europe and the role of intermittent wind and solar power technologies is significant and growing in the electricity sector (European Commission, 2015b). As more power is produced with renewables also the dependence of power production on climatic factors strengthens. Together more renewable production, climate change and increasing grid connections between member countries (the 'Energy Union', see European Commission, 2015a) raise the question of how transnational climate impacts affect power

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systems?

If the effects are significant specific adaptation to transnational impacts might be necessary in the design of international and national power systems and markets. Comparable issues arise in adapting to changing energy markets that result from climate change mitigation across borders (e.g. Singh et al., 2016). While our study focuses on a renewable resource, it is good to bear in mind that climate change can also impact thermal and nuclear power production (Mima and Criqui, 2015) and affect international power markets: for example in France during the heat waves of 2003 17 power plants had to be shut down or reduce their output due to the shortage of cooling water which forced the country to import electricity at a price 10 times the normal cost (Ackerman and Stanton, 2008). As energy is a vital part of today's society, changes in supply can have far reaching cross-sectorial consequences (Rasul and Sharma, 2015). We contribute to the discussion on transnational impacts by analysing the potential cross-border impacts of possible climate change driven changes in the hydropower potential. We analyse this in the context of the Nordic countries where Norway and Sweden are likely to face climate change effect by clearly gaining hydropower potential. Finland is a member in the common Nordic power market and is likely to experience transnational impacts. The climate change effect to Finland is more indirect by nature mainly because the hydropower share in the power system in Finland is considerably lower than the ones in Sweden and especially in Norway, and consequently main effect comes through the mechanisms power pool.

The market we study is generally characterized by a diversified production structure dominated by hydropower. We use an economic simulation model of the Nordic power market and a dynamic optimization model for hydropower to study the impact of climate change on hydropower production in the Nordic market. Climate change is a potentially important driver as it can influence both on the hydropower potential and on the annual inflow patterns that both affect to the operation of the power market. We analyse two different hydropower scenarios (and baseline) affecting to the hydropower potential and inflow. Scenarios are based on the analyses of changes in the Nordic Power system due to changes in climate conditions (Styve et al., 2012). Styve et al. (2012) use climate models “DMI-HIRHAM-Echam5” and “met.no-HIRHAM-HadCM3” (from now on referred to as Echam and Hadam) as a basis of their power system analysis. Our analyses differs from Styve et al. (2012) in the sense that in our analyses thermal production mix is endogenized and two inflow profile tendencies (flatter spring peak and increased total) are separated and simplified. We explore impacts to the production mix, the price of electricity, consumption of electricity and emissions from electricity production.

The rest of the paper is structured as follows. In chapter 2 we present the Nordic power market that functions as the pathway for transnational impacts in our analysis. We also present possible climate change impacts on hydropower production as well as climate change and energy policies that reshape the Nordic energy markets. We then move on to describing the model and data used to simulate the power market in chapter 3. The results and their potential transnational implications to Finland are presented and discussed in chapter 4. Chapter 5 draw conclusions and policy implications on the significance of the findings for future energy and climate policies.

2. The Nordic power market and climate change

2.1. The production structure

The Nordic power market was the first international power market and it was formed by four Nordic countries Norway, Sweden, Finland and Denmark.[1] Depending on the year more or less half of the power produced in the Nordic countries is based on hydropower. Nuclear power has also a significant share in the production mix. The rest consists mostly of wind power, power produced in combined heat and power plants (CHP-plants) and in separate power production plants[2] (ENTSO-E, 2016). In Finland the total supply of electricity was about 87 TWh in 2014 (Finnish Energy, 2016). The Finnish production mix consists mostly of nuclear power (23 TWh in 2014) and other thermal power (28 TWh) as well as hydropower (13 TWh). Other thermal power is mostly produced in combined heat and power plants but also by separate power production plants. Wind power accounted for only 1 TWh in 2014 but its share is going to grow in the future (Finnish Ministry of Employment and the Economy, 2010). Cross-border trade plays a crucial role in the total supply in Finland: in 2014 ca. 25% of the total supply was imported. Imports play an important role also in the peak supply: in 2016 a new hourly power peak record was set in Finland at 15 100 MW of which 10 800 MW was domestic production and 4 300 MW was imported from the neighbouring countries (Finnish Energy, 2016).

Energy prices are partly driven by climate and weather related variables in the Nordic market (other factors include demand, production costs, emission allowance prices (EU ETS), availability of nuclear power and bottlenecks in the transmission grid) (NordREG, 2014a). The high share of hydropower in the production mix has historically kept the price of electricity in the Nordic countries lower than in southern Europe. According to Kauppi (2009) the variability of the inflow between years has set the direction of trade between the thermal oriented countries (Finland, Denmark) and hydro oriented countries (Norway, Sweden) in the Nordic markets. As hydropower has negligible fuel costs, rainy (dry) year or period decreases (increases) the wholesale price of electricity.[3] Hydropower has special characteristics as it can store water in reservoirs and generate power when it is consumed with low variable costs. Furthermore reservoirs make it possible to level the difference between inflow of water and demand for electricity around the year. In a typical year Nordic reservoirs are filled during late spring-early autumn and emptied during winter when the demand for electricity is at its highest (Kauppi, 2009).

2.2. The effects of climate change

According to the Nordic research project ‘Climate and Energy Systems’ or ‘CES’ (2012) ‘there is little doubt that the Nordic and Baltic hydropower systems will be affected strongly by a changing climate’ (Nordic Council of Ministers et al., 2012, 141, see also Graham et al., 2007; Lehner et al., 2005; Olsson et al., 2015; Seljom et al., 2011; Veijalainen, 2012). The hydropower potential will change from place to place, although there are large uncertainties considering the results. According to CES-project in Nordic countries climate change can generally increase the inflow of water with an emphasis in the colder and milder months and make spring floods earlier and smaller. In some areas dry periods in the summer may increase. In the CES-project climate change impacts were mostly studied between future climate scenarios (2021–2050) and a reference climate (1961–1990) using the emission scenario SRES A1B (Nakicenovic and Swart, 2000). Out of various climate change modelling scenarios two are presented for the whole region and in these scenarios the reservoir inflow increases considerably, by 10,8–12% (Nordic Council of Ministers et al., 2012, 182). Inflow increases mostly in Norway (ca. 15 TWh) and Sweden (ca. 10 TWh) where most of the hydropower in the Nordic market is produced, but also in Finland (ca. 1 TWh).

In this study we have made two scenarios on the changes in

[1] The framework for an integrated Nordic power market contracts was made in 1995 and a joint Norwegian-Swedish power exchange was established. Finland joined to the power exchange in 1998 and Denmark in 2000.

[2] The production shares by fuel sources in 2016 were: hydropower 56%, nuclear power 21%, wind power 8%, fossil fuels 8% and biofuels 6% (ENTSO-E, 2016).

[3] Depending of course also on the amount of water already in the reservoirs.