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## The Economics of Carbon Dioxide Removal Technologies using Equilibrium Modelling

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### Introduction

The recent IPCC report presented that carbon dioxide removal (CDR) will have a critical role to play in meeting the 1.5°C objective. This objective can hardly be attained without a large-scale deployment of CDR methods (IPCC, 2022). This study examines the economics of a large-scale and market-driven deployment of CDR technologies, namely bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS), using a spatial and dynamic equilibrium model. That model allows us to investigate the CDR technologies that will be deployed, their localization, and quantity. However, it will be impacted by the negative emission price that is determined at the supply and demand equilibrium. It is allowing us to investigate this CDR deployment effect on negative emission price and the impact of future demand of negative emissions on all previously named components.

### Methods

Our approach is a year-by-year model from 2025 to 2050 that focuses on the Northern Sea adjacent countries. Our methodology mobilizes non-cooperative game theory concepts as we model the economic interaction between agents subject to an endogenous CO<sub>2</sub> price using a Generalized Nash Equilibrium problem formulated as a mixed complementarity problem à la Gabriel et al., 2012 or Abada et al., 2013. We calibrate the model using recent data and projections for 2050 from various sources. In our situation, we have 7 regions (France, Benelux, Germany, Denmark, Sweden, Norway, and the UK) that compete in investing in BECCS and DACCS each year. It is important to note that BECCS can only be achieved on already existing facilities with biogenic CDR potential (Rosa, 2021). Their goal is to maximize the net present value of the profits that will be made during the whole period. On the other side, we have the demand for negative emissions. We created two types of demand scenarios. First, we have an exogenous demand (model A) corresponding to a situation in which companies or governments must buy negative emissions, being price-takers. In the second scenario, we have an endogenous demand (model B) which here represents a situation where companies or governments must reduce their emissions with two levers, abating emissions or buying negative emissions. This demand is modeled with 2 main components: Government pledges to negative emissions (Carbon Gap, 2024), and the marginal abatement cost curve of hard-to-abate sectors (Yue et al., 2020). We

created three levels of demand: high, moderate, and low. The following section investigates the moderate demand scenario.

### Results

Our results provide detailed projections of the technologies that will be deployed, including their scale, geographic distribution, and projected timelines (Figures 3 and 4). In addition, our findings assess the supply-demand effect on net negative emission price (Figure 1) and the amount of net negative emission (Figure 2). The “net” means that we considered the whole supply chain’s emissions and removed it from the output. The results express investments in a market-based situation, any form of subsidies can modify the curves. For instance, subsidizing the difference between the red and the blue lines in Figure 1 would increase the amount of net negative emission by the gap between the two lines in Figure 2. BECCS investments are dominated by transport and storage infrastructures, and biogenic CDR potential. For DACCS, it is mostly depending on energy cost and its CO<sub>2</sub> efficiency. To stay competitive, governments need to subsidize transport and storage infrastructures or energy decarbonization would incentivize BECCS and DACCS investments without direct subsidies. If not, direct help is needed for regions investing in the latest.

Figure 1

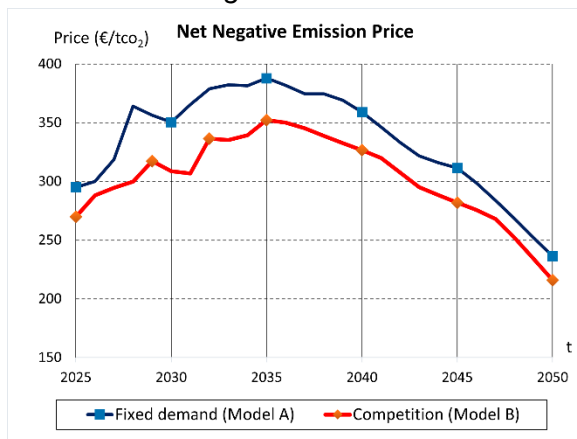


Figure 2

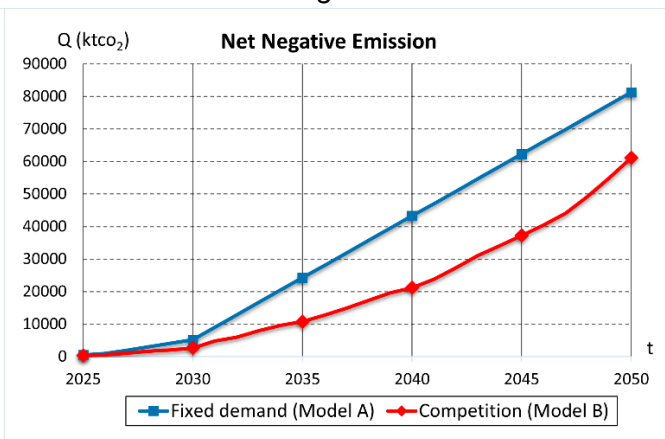


Figure 3

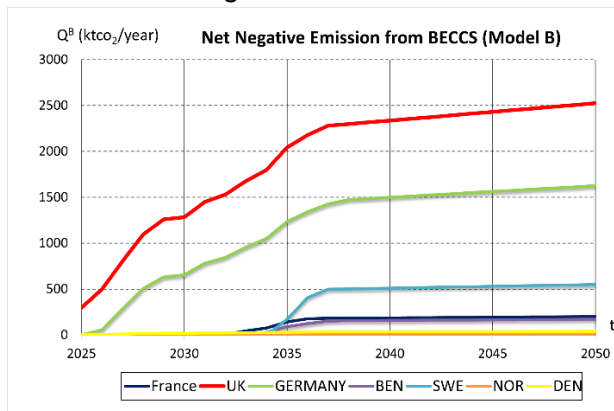
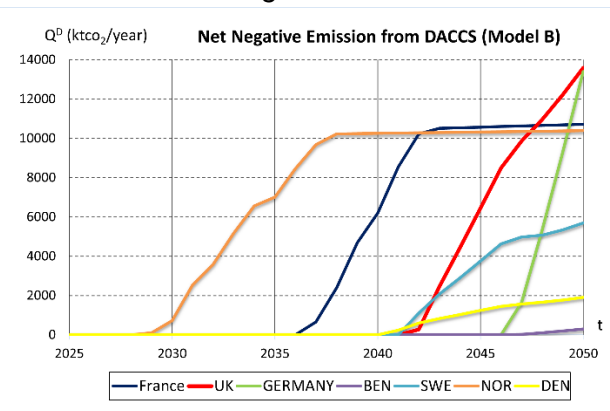


Figure 4



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