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None of these authors have ties to the energy industry or to any of the industries that might be impacted by decarbonization.

Auctions to Procure Negative Emissions at Industrial Scale

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Pledges to achieve climate goals by jurisdictions and corporations describe a net zero outcome where anthropogenic emissions fall substantially but typically remain at 10-15 percent of 2005 levels by 2050. Many of the residual emissions will be associated with the industrial sector, where process changes and other technologies that can reduce emissions are unable to practically achieve absolute zero emissions. To halt greenhouse gas accumulation, these remaining emissions must be balanced by negative emissions achieved through biological processes (e.g., on natural and working lands), or mechanical means (e.g., through direct air capture of carbon coupled with utilization or storage). Biological processes offer enormous opportunity but are challenging to properly incentivize, validate, and monitor, especially because of their distributed nature. Consequently, to meet climate pledges, actors are looking to industrial scale projects that exploit technical knowledge and value chains in the sector, including direct air capture. Another example is carbon capture and storage at bioenergy facilities (bioenergy with carbon capture and storage, or BECCS). If the life cycle emissions of biofuels are small, then the capture and storage of carbon that is released during their combustion results in net-negative emissions while providing useful energy at an industrial scale.

The individual elements of the industrial-scale production of net-negative emissions are proven technologies, but their coordination and application at a commercial scale remains a monumental task with substantial investment risk regarding cost and performance. These investments are expected to come from the private sector but will likely require government incentives through direct subsidies and risk sharing in some form. At least in the near term, the technologies for capturing and sequestering carbon are likely to be very capital intensive and to exhibit increasing returns.

A useful example is the initiative by the Swedish Energy Agency to provide approximately 3.5 billion euro to support the development of BECCS in the domestic energy and wood products industries. This support will be allocated through a reverse auction that seeks to maximize the amount of emissions sequestered given the fixed procurement budget. Due to the large capital costs, this case is similar to that of the pharmaceutical procurement problem analyzed in Baranov et al. (2017) where the producers have increasing returns. We use laboratory experiments to test a version of the auction mechanism proposed in that paper for the context of the procurement of CO2 sequestration. Because the carbon capture technology will be retrofitted onto the existing industrial facilities, it will have a fixed maximum capacity. Due to the large fixed costs, the minimum quantity offered will rise with a declining price, but

the maximum capacity will likely not change. The auction procedure provides that the bidders offer a quantity range, a minimum and a maximum, for the amount of sequestration they would be willing to provide at a given price. We explore modifications of the auction implementation for their effects on the potential for collusion in the small-numbers case.

As in the case of Sweden's energy and wood products industries, it will often be the case that a small number of large firms will be well-positioned to bid for payments to capture emissions. We examine various bid structures in static and dynamic auction formats, with discriminatory versus uniform settlement designs and information treatments that may affect the possibility for collusion. We test a set of modifications to the Banarov et al. design that may reduce the likelihood of collusion among the small number of participating bidders.

A potentially important influence on bidder behavior will be the determination of ownership rights for the carbon credits that are produced. We compare a setting in which the government assumes ownership, essentially procuring carbon credits, with one in which the investor retains ownership of the credits which may be marketable domestically, or perhaps internationally. An important institutional uncertainty concerns the outcome of Article 6.2 negotiations under the Paris climate agreements that will govern the transferability of credits and their proper accounting toward national climate goals. We examine the effect of allowing firms to retain a share of the offsets they produce for sale on the international market. In the presence of increasing returns, we expect that this may provide a way to increase the leverage of the direct subsidy in producing increased sequestration for the limited budget amount.

This research has broad relevance to industrial decarbonization. It is likely that many opportunities for carbon capture in industrial processes such as cement or petrochemicals will share the key characteristics of increasing returns and small numbers of participating producers. Developing reliable mechanisms for inducing emission reductions will become increasingly important in these otherwise recalcitrant sectors.

Baranov, Oleg, Christina Aperjis, Lawrence M. Ausubel, and Thayer Morrill. 2017. "Efficient Procurement Auctions with Increasing Returns." American Economic Journal: Microeconomics, 9 (3): 1-27.