STEERING THE DIRECTION OF INVENTORS AND INNOVATION WITH SUPPLY VS. DEMAND POLICIES

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Motivation and Research Question

Accelerating innovation in the energy sector and steering it toward clean technologies is one of today's most pressing challenges. Doing so requires increasing the quantity and quality of human capital focused on clean energy innovation and the more basic science that enables it. Yet, relatively little is known about what interventions increase the supply of inventors most effectively. Policymakers can implement a wide range of incentives, such as human capital policies and technology-push subsidies for R&D on the supply side or market-pull pricing mechanisms on the demand side. Government resources are limited, though, so it is important to determine which interventions can achieve the greatest "bang for the buck."

Growing evidence shows that demand-side mechanisms can increase firms' incentives to invest or innovate (Aghion, Dechezleprêtre, Hémous, et al. 2016; Calel 2020; Calel and Dechezlêpretre 2016; Newell, Jaffe, and Stavins 1999; Popp 2002, 2019). However, their effects on inventor entry depend on the elasticity of labor supply of scientists and inventors, which can be relatively inelastic in the short run (Goolsbee 1998). Furthermore, the equilibrium cost of R&D increases when supply is inelastic, dampening the incentive for firms to invest. On the other hand, supply-side interventions should directly increase innovation not only in the short run but also the long run due to path dependency. They also reduce the cost of research, which then enhances incentives for firms to invest (Van Reenen 2021).

In this paper, we examine how supply- and demand-side policies affect scientists' research topic choice and innovation outputs. We first focus on early-stage researchers by studying Ph.D. students' dissertation topic choices. We then study innovation outcomes as measured by patents. Our aim is to identify a setting in which both carbon pricing and direct subsidies for academic energy R&D co-exist, allowing us to use quasi-experimental methods to estimate comparable measures of the marginal effects of public spending.

Data Sources and Empirical Design

We are gathering data covering several decades of U.S. Ph.D. dissertations and plan to apply natural language processing methods to classify research topics as being related to clean or dirty energy.

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This will capture the direction of innovation at the earliest stage of scientists' careers. Ideally, we will match scientists observed in the dissertation data to patents from PATSTAT to study their innovation outputs over their careers. We are still in the process of determining the feasibility of merging these two datasets. However, even without such matching, we will be able to study the effects of supply- and demand-side policies on innovation output separately.

We will start by modeling individual Ph.D. students' decisions as they choose a discipline and their specialized topics, and then whether they choose to become a "patenter," as follows:

$$Y_{ict} = \alpha + f(\text{Supply Policy}_{it}) + g(\text{Demand Policy}_{it}) + \varepsilon_{ict}\,, \tag{1}$$

where Y_{ict} is inventor i's dissertation or patent metric (e.g., count, citations, novelty) in energy technology class c (clean or dirty) in year t. Supply Policy$_{it}$ and Demand Policy$_{it}$ are the two types of energy policies that individuals face in year t. Various controls and fixed effects will be included.

Identifying causal effects will require exogenous variation in each policy to account for endogenous sorting as well as finding a setting where they co-exist. We are currently developing our research design. We may use energy-related price shocks to proxy for demand-side market-pull policies, utilizing data on the tax-inclusive prices of coal, oil, and natural gas at the country-year level from the IEA's Energy Prices and Taxes. These are exogenous to the decisions of individual inventors. Regarding supply-side policies, we are exploring some promising avenues that involve adapting identification strategies from the education economics literature.

We will then estimate a more aggregated reduced form production function at the technology level, i.e., a function that relates the stock of Ph.D.-trained researchers in various disciplines and demand-side policies to the flow of patents in a particular technology as follows:

$$Y_{ct} = \alpha + f(\text{Stock of Active Ph.D.s}_{dt}, \text{Overlap}_{cdt}) + g_c(\text{Demand Policy}_t) + \varepsilon_{ct}\,, \tag{2}$$

where Y_{ct} is the patent metric for technology class c (clean or dirty) in year t, and d is a Ph.D. discipline index. Demand Policy$_t$ is as described above. Overlap$_{cdt}$ describes the technically feasible connections between disciplines and technologies. Mapping such "overlap" while accounting for the high likelihood of spillovers across research areas requires constructing the regression sample in a way that the SUTVA holds. We will use quantitative text analysis methods and econometric techniques to address this (e.g., Myers and Lanahan 2021).

We also plan to investigate specifications that allow f to vary by discipline. We have a theory that the "interdisciplinary-ness" of energy technologies might yield a much weaker relationship between the stock of active Ph.D.-trained researchers and ultimate inventive output relative to more disciplinary-based innovations due to the costs of coordinating knowledge (e.g., getting materials scientists to work with electrical engineers). It will be of general interest to see how this relationship varies across technologies and disciplines.

These two sets of analyses will allow us to compare the relative merits of supply- and demand-side policies for increasing the supply of inventors and spurring innovation, providing insight into which policy design most cost-effectively steers the direction of innovation. The ideal comparison can be made if both sources of identifying variation are in dollar terms. This may be possible, but if not, we can still estimate something close to the marginal cost of producing another Ph.D. graduate who is trained in a particular discipline so that we can make an apples-to-apples comparison of supply- and demand-side energy innovation policies.

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Conflict of Interest Statement

With regards to the research described in this abstract, the authors have no relevant or material financial interests to declare.