The Private Value of Clean Energy Innovation

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Technological innovation in the production of clean energy is a key element in the transition to a net-zero economy. Given important environmental and innovation externalities, the private sector is unlikely to invest adequate resources in producing such innovations, and this has generated substantial interest in policies that increase clean energy innovation. However, we have witnessed a substantial drop in (patented) innovation over the last decade, with negative annual growth rates of 5.5% (Popp et al, 2020; Probst et al., 2021).[1] To understand which policies might reverse this trend, it is important to understand the mechanisms behind a shift away from clean energy innovation.

We propose that studying the evolution of the private value of clean energy innovations can inform us about the importance of potential mechanisms identified in the literature. First, changes in fuel prices or the emergence of new fossil fuel technologies (Acemoglu et al, 2020) may have increased the attraction of 'dirty' technologies. Second, decreasing real wages in the wake of the financial crisis may have undermined the willingness to pay for clean energy products. Third, financing of green R&D – which could be inherently riskier – may have become more difficult due to increased risk aversion or financial market regulation. Fourth, the wave of clean energy innovation preceding the recent slump (i.e. from the 1990 to around 2011) might have been so successful that it exhausted easy innovation options and 'clean' ideas are now harder to find.

These explanations imply different predictions with regards to the evolution of the distribution of private values over time. For instance, we would expect that 'demand pull factors' such as reduced fossil fuel prices translate into a reduction of the value of clean compared to fossil fuel based dirty innovation. If financial constraints have become more binding, this should translate into an increased value of the marginal green project because of a higher cost, but the values of infra-marginal projects should have remained stable. If the supply of new ideas has stalled, we should observe a decreasing number of particularly high value technologies. We propose to compare these predictions to the patterns in the data to come to grips with the potential importance of the mechanisms proposed.

To conduct this explorative study, we will develop an improved method to estimate the private value of innovations. Our method builds upon the event-study approach developed by Kogan et al. (2017). This market-based approach values innovation by measuring market-adjusted returns to a firm's stock around the day a patent grant is announced. This event study approach is attractive in that it recovers how the market responded to the news of a successful patent application. However, it suffers from the standard bias in event study analysis: the change in the stock price only recovers the full value of new information if that information is a complete surprise. If the market anticipates that a firm could be granted a patent, then the stock price will have already internalized some of the value of the potential patent before the patent announcement is made. Adjusting for this requires estimating the probability with which the market expects a patent grant.

Kogan et al. (2017) assume a fixed probability of 0.56, which is equal to the observed frequency of successful patent applications between 1991-2001. However, this probability may vastly differ based on the underlying technology. Technologies that provide a clear but incremental contribution to a firm's past innovation may be more likely to be granted than more novel, hard-to-evaluate innovations. In addition, some sectors may have a harder time obtaining patents than do others. If the market incorporates these

[1] Probst et al. (2021) find that the average annual growth rate in climate change-mitigation technology patents has dropped from of 10.4% between 1995-2013 to -5.5% between 2013-2018. Popp et al. (2020) find a peak around 2011 and show that the decline is present in all technology fields. Both articles find that overall patenting has increased steadily since 2009.

differences in probabilities, the estimated value of patented innovations could be off by a considerable margin – and those errors could be correlated with technological characteristics.[2]

We address this problem by implementing a new market-based approach to estimating event probabilities (Langer & Lemoine, 2021). By estimating how the prices of out-of-the-money options change when information becomes available, we can recover the market's priced-in probability of that information. In particular, if a patent is likely to increase a firm's stock price, then a high-priced call option could be valuable if the patent is granted but be nearly worthless if it isn't. The value of the option on the day before the patent is announced is a weighted average of the value of the option if the firm gets the patent and the value if it doesn't. If the latter value is nearly zero, then the ratio of the day-before option price to the day-after price is the risk-neutral probability that the market places on the firm being granted the patent. This approach allows us to estimate patent-specific probabilities and should therefore result in improved estimates of patent value. Further, any differences in these probabilities between green and brown energy patents would be interesting in and of themselves since they would reflect market perceptions of each type of innovation.

Our proposal will advance knowledge and policy in three ways. First, by adjusting for variation in patent probabilities, we will more accurately depict the evolution of the value of green energy innovation. Second, we will highlight the importance of the different mechanisms that could have driven the drop in clean energy patenting. In particular, our work should inspire further research that can causally pin down the effectiveness of innovation policies to improve clean energy technology. Finally, we will improve the methodology used to measure the value of patents. These values are widely used in the economics of innovation, so we expect our new methods to be influential.

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Conflict of interest statement: *The authors declare that they do not have any financial or other interests that might bear on the proposed work.*

[2] Note that the change in a firm's total value around the day of grant should be multiplied by $\frac{1}{1-\pi}$, where π is the probability of grant as evaluated by the market. This means that an increase in this probability from 0.56 to 0.66 implies an increase of 29.4% in the estimated value.