Modeling Renewable Energy Innovation: Research Proposal

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One of the keys to mitigating climate change is the switch from fossil fuels to renewable energy sources. Currently, renewables such as wind, solar and bio-fuels are too expensive to compete with traditional dirty fossil fuel energy sources such as coal and oil. Significant innovation in renewable energy production must take place to make it cost efficient, in order to phase out fossil fuels and achieve sizable climate change mitigation. Hence, finding the environmental policy that will encourage innovation in renewable energy production is a vital task for environmental economists.

However, there are many complications which make achieving sizable innovation in renewable energy difficult. For instance, there is significant uncertainty with respect to the pace of innovation and productivity of investment in renewables. Uncertainty about future economic conditions as well as the damages from climate change, makes long-term investments such as in renewable R&D inherently risky. The indeterminacy of many renewable energy sources (such as solar and wind) further complicates the process of fully phasing out fossil fuels.

To determine the optimal policies that foster the switch to renewable energy, these and other complications need to be taken into account. I propose to use calibrated integrated assessment models to examine these issues and determine the market incentives to renewable energy innovation, the optimal amount of government intervention needed to speed up said innovation, and the magnitude of emission reduction that renewables can generate. Below I describe two specific projects which contribute to this goal. The first examines how renewable R&D investment is affected by uncertain fossil fuel prices. The second studies the unique nature of clean innovation (input cost-reduction versus the more typical productivity increase) and whether that changes previous seminal results on government intervention.

Fossil Fuel Price Volatility and Renewable R & D

An important factor that determines the demand for renewable energy technology is the price of fossil fuels. The fact that oil is relatively cheap allows it to dominate the energy market. Higher oil prices increase demand for renewable energy, increasing investment in renewable technologies which produces cost-saving innovation. Many environmental economic models assume that the market price of oil is either static or follows some deterministic path, set by the supplier. However, in the real world that is not the case - oil prices are very volatile, subject to various geo-political shocks. As prices of fossil fuel affect the demand for renewables, oil price volatility has an effect on investment in renewable energy innovation. This study sets out to examine this effect.

Previous theoretical results following from "The Real Option Theory" (see Dixit and Pindyck (1994)) tell us that uncertainty over future returns decreases irreversible investment. Blyth et al. (2007) apply this story to investment in green energy, finding that uncertainty about future climate policy reduces investment into more environmentally friendly gas power plants and carbon capture and storage capacity. Fuss and Szolgayová (2010) similarly find that uncertainty about technological progress and fossil fuel prices reduces investment into renewable energy capacity. However the results in this study are driven by the assumption that once investment into green technology is made, the investor commits to using renewable technology. Chen and Tseng (2011) find that when investment in new gas plant does not commit the firm to using it (i.e. the firm can switch back to using coal if environmental policy becomes lax), such an investment can serve as a hedge against stringent environmentalism and increases with environmental policy uncertainty. Albrizio and Costa (2012) model both investment in building a new a natural gas plant without committing to using it and a more typical investment in carbon capture and storage capacity committing to its use and confirm that the need to commit to a technology drives the investment reduction under uncertainty.

All of the previously mentioned studies examine investment in increasing renewable energy capacity. We add to the literature by studying how oil price uncertainty affects cost-saving innovation in renewables. This problem is more complex than studying investment into capacity, as investment in renewable innovation has non-linear pay offs. However, cost-reduction in renewables does not commit the firm to using renewables in case oil is cheaper. I will determine whether investing in renewable $R\&D$ can serve as a hedge against high oil prices and hence if benefits of renewable R&D increase as fossil fuel prices become more volatile. I will also determine the key parameters which determine the nature of the effect (such as the degree of the substitutability between renewables and fossil fuels, the productivity and cost of Renewable R&D and the discount rate). I will then proceed to use data to empirically estimate the values of such key parameters, and use the estimates to calculate optimal renewable innovation policy response to fossil fuel price volatility.

Renewable R&D With Decreasing Returns

(Joint project with Carolyn Fischer, Resources for the Future)

The seminal papers by Acemoglu (1998, 2002) posit a model of differentiated technological change across two factors of production to explore bias in technological change. He identifies the driving roles of prices (factor scarcity), market share (factor abundance), and substitutability. The initial applications were to explain productivity changes in labor markets between skilled and unskilled workers. However, the directed technical change (DTC) concept also seemed apt for this climate policy question. Acemoglu et al. (2012), (henceforth AABH) apply this model to the question of biased technical change among two different factors: clean and dirty energy. They arrive at the compelling conclusion that, under the right circumstances, an initial and temporary public investment into green innovation can be sufficient to push the world on a path towards sustainability, and that more generally R&D policy has a stronger role to play than carbon pricing. This result is in contrast with many previous studies (Nordhaus (2008), Stern (2007)) that show that a more permanent government intervention with carbon pricing at the center is needed to avert climate change.

An important question is whether the adapted AABH model of DTC is the most appropriate option for thinking about climate policy. Some studies have questioned the parameterization and inattention to welfare costs (e.g., Hourcade et al. (2011)). Others have explored the role of patent duration assumptions (Greaker and Heggedal, 2012) or learning spillovers (Mattauch et al., 2012). We believe a key model assumption in AABH is that investment in innovation has increasing returns.

In AABH, as productivity in a given sector grows, innovation in that sector becomes more and more productive. This standing on the shoulders of giants dynamic implies that once a significant amount of innovation has taken place, further innovation follows, resulting in an explosive growth in productivity. While these dynamics may be realistic when modeling productivity growth in the production of consumer goods and services (Acemoglu, 2002), it is not entirely appropriate for energy innovation. The majority of renewable energy innovation involves reducing the cost of energy production. However due to physical limitation, energy production can never become entirely free there is a lower bound on renewable energy production cost. Hence, as more energy innovation takes place, the returns on further innovation should be diminishing. At the same time, multiple kinds of innovation occur in an economy: some are productivity enhancing, while others are quality or variety enhancing. It seems more plausible that factors producing a representative consumer good may experience exponential productivity growth, while factors producing an energy input may experience diminishing productivity growth.

We propose to incorporate these dynamics into a model of directed technical change. Rather than splitting the economy into clean and dirty inputs as in AABH, we instead focus on the split between the energy and final goods sector innovation. For final goods, productivity returns are increasing, while in the energy innovation takes the form of renewable energy cost reduction with decreasing returns. We then proceed to investigate whether with these dynamics the optimistic result of AABH is still feasible.

References

Daron Acemoglu. Why do new technologies complement skills? directed technical change and wage inequality. *Quarterly journal of economics*, pages 1055–1089, 1998.

Daron Acemoglu. Technical change, inequality, and the labor market. *Journal of Economic Literature*, 40 (1):7–72, 2002.

Daron Acemoglu, Philippe Aghion, Leonardo Bursztyn, and David Hemous. The Environment and Directed Technical Change. *American Economic Review*, 102(1):131–66, February 2012.

Silvia Albrizio and Hélia Costa. Policy uncertainty and investment in low-carbon technology. *Available at SSRN 2165214*, 2012.

William Blyth, Richard Bradley, Derek Bunn, Charlie Clarke, Tom Wilson, and Ming Yang. Investment risks under uncertain climate change policy. *Energy policy*, 35(11):5766–5773, 2007.

Yihsu Chen and Chung-Li Tseng. Inducing clean technology in the electricity sector: Tradable permits or carbon tax policies? *Energy Journal-Cleveland*, 32(3):149, 2011.

Avinash K Dixit and Robert S Pindyck. Investment under uncertainty, 1994. *Princeton UP, Princeton*, 1994.

Sabine Fuss and Jana Szolgayová. Fuel price and technological uncertainty in a real options model for electricity planning. *Applied Energy*, 87(9):2938–2944, 2010.

Mads Greaker and Tom-Reiel Heggedal. A comment on the environment and directed technical change. Technical report, Research Department of Statistics Norway, November 2012.

Jean-Charles Hourcade, Antonin Pottier, and Etienne Espagne. The environment and directed technical change: comment. Technical report, Nota di lavoro, Fondazione Eni Enrico Mattei: Climate Change and Sustainable Development, 2011.

Linus Mattauch, Felix Creutzig, and Ottmar Edenhofer. Avoiding Carbon Lock-In: Policy Options for Advancing Structural Change. Working papers, Department of Climate Change Economics, TU Berlin, February 2012.

William D. Nordhaus. *A Question of Balance: Weighing the Options on Global Warming Policies*. Yale University Press, 2008.

Nicholas Stern. *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Campridge, 2007.