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Advanced solar R&D: Combining economic analysis with expert elicitations to inform climate policy

Erin Baker [a,*], Haewon Chon [b], Jeffrey Keisler [c]

[a] 220 Elab, University of Massachusetts, Amherst, MA 01003, United States
[b] Joint Global Change Research Institute, University of Maryland, 8400 Baltimore Avenue, Suite 201, College Park, MD 20740, United States
[c] College of Management, University of Massachusetts, Boston, MA 02125, United States

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ABSTRACT

The relationship between R&D investments and technical change is inherently uncertain. In this paper we combine economics and decision analysis to incorporate the uncertainty of technical change into climate change policy analysis. We present the results of an expert elicitation on the prospects for technical change in advanced solar photovoltaics. We then use the results of the expert elicitations as inputs to the MiniCAM integrated assessment model, to derive probabilistic information about the impacts of R&D investments on the costs of emissions abatement.

1. Introduction

In this paper we combine expert elicitations and economic modeling to analyze the potential for R&D into solar photovoltaics (PV) to impact climate change. When it comes to the question of what to do about climate change, the role of technical change is large. Estimates of the costs of control and of eventual damages both depend heavily on assumptions about technical change (Edenhofer et al., 2006; Popp, 2006). In order to craft good climate change policies — whether they are emissions policies or technology policies — we need to understand how technical change responds to policy, and how emissions respond to technical change. Technical change can come through two channels — investment in R&D and learning by doing. We focus primarily on R&D, but our analysis of how improvements in technology will impact costs is also relevant to learning by doing. We note that a wide variety of policies can impact investment into R&D, from policies that directly allocate government funds to R&D, to R&D-tax incentives, to carbon taxes, to adoption incentives. For this paper, we focus on R&D investment directly, and leave the analysis of the government's role in R&D investment to future research. We focus on how R&D impacts technical change, and how technical change impacts the cost of reducing carbon emissions. Specifically, we study the impacts of technical change on the entire abatement cost curve, which measures the costs of abatement, defined as a reduction in greenhouse gas emissions, at each level of abatement between zero and 100%.

We note two gaps in the current literature. First, there is very little work that directly addresses the fact that the results of investment in R&D are inherently uncertain. This topic is just starting to be studied, most notably by others in this special issue (Blanford, 2007; Bohringer and Rutherford, 2006; Bosetti and Drouet, 2005). Second, there is virtually no work that discusses how particular technologies are likely to impact the abatement cost curve. Yet, for decisions made under uncertainty, it is the shape of the whole curve, and not just a point estimate, that determines results. Thus, we need to understand the impact of technology on the abatement cost curve, for many different levels of abatement. The difficulty here is that not all technical change is alike, and not all R&D programs are alike. Different types of technologies

* Corresponding author. Tel.: +1 413 545 0670.
E-mail addresses: edbaker@ecs.umass.ed (E. Baker), hwchon@gmail.com (H. Chon), jeff.keisler@umb.edu (J. Keisler).

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will impact the abatement cost curve in different ways. For example, an incremental improvement in a non-carbon transportation technology may have a very small effect on the cost of abating a small amount of emissions, because of infrastructure and network effects. If climate change damages turn out to be very severe, however, then even small improvements in non-carbon transportation technologies may be very important. On the other hand, consider improvements in coal-fired electricity generation. An incremental improvement is likely to have a large impact if damages are low and abatement is minor; but virtually no impact if damages are extreme and a no-carbon world is desirable. Another distinction between R&D programs is their levels of risk. Some programs provide a possibility of a breakthrough, but also a large chance of failure. Other programs are less risky, aiming only to improve the technology incrementally.

In Baker et al. (2007) we described a general framework for quantifying the uncertainty in climate change technology R&D programs and their associated impacts on emissions. Here, we present an implementation of that framework, focusing on advanced solar technology. Fig. 1 illustrates the flow of the data in this framework; the actions placed within the box are discussed in this paper; the actions outside the box are applications of the outputs of this paper. The first step of the project, discussed in Section 2, is collecting probabilistic data on advanced solar PV technologies through expert elicitations. The products of the elicitations include explicit definitions of success for each technology, and probabilities of success for given funding trajectories. In Section 3 we determine how the technologies would impact the abatement cost curve, if they achieve success as defined. For this step we use MiniCAM, a technologically detailed Integrated Assessment Model (IAM), to determine the impact of each technology on the Marginal Abatement Cost (MAC) Curve. In Section 3.4 we discuss the parameterization of each technology's impact on the MAC. In Section 4, we combine the probabilities with the impacts on the MAC to derive multiple representations of the probabilistic impacts of R&D. As shown in the figure, these can then be combined with probability distributions over climate damages in technology policy models. We conclude in Section 5.

2. Expert elicitations

In this section we discuss the steps in the expert elicitation, including the selection of particular technologies, and the development of definitions of success. We then discuss how we structured the probability assessments and the results of those assessments. The output from the expert elicitations are specific definitions of success for each R&D project, and probabilities of success for each of those projects, given specific funding trajectories.

2.1. Why use subjective probability assessments?

To consider the uncertain impacts on the MAC from a portfolio of candidate technologies, we must estimate the probability that, given a specified research policy, each of the technologies will meet given working definitions of success. For some technologies, there are helpful historical data and historical comparisons, e.g., Moore's law from the semiconductor industry, and manufacturing learning curves (Ruth, 1993; Yelle, 1979).

With highly innovative technologies, however, history provides only sketchy guidance. In such cases, common to R&D management, decision analytic techniques are often used to obtain the necessarily subjective judgment of experts who are most familiar with the specific technologies (Clemen and Kwit, 2001; Peerenboom et al., 1989; Sharpe and Keelin, 1998).

We are considering breakthrough solar PV technology in particular. Basic research is needed (e.g., to find appropriate molecules that have the potential for sufficient performance that PV cells using them might be widely deployed), followed by development work to move research from the lab to production (e.g., finding the right manufacturing processes), at which point improvements would follow a more predictable path. To the extent that probability of achieving success depends on breakthroughs, what has happened with other technologies will not offer much to differentiate paths that are particularly promising. Experts can provide useful judgments about the likelihood that research will overcome particular hurdles, and these expert judgments can be combined to estimate overall probability of success for each technology (Howard, 1988). We have not asked the experts to provide judgments on what the overall economic benefits of the technologies will be, since these depend on economy-wide developments, such as whether a vastly improved regional or national electric grid is available to transmit electricity great distances with minimal power loss. We discuss the estimation of the economy-wide impacts of technical change in Section 3 below.

2.2. Technologies considered

Our effort is focused on how current R&D can affect abatement costs in the electricity sector forty or fifty years in the future. We identified experts recognized for expertise in solar PV technology in general, and with separate areas of specialization collectively covering much of solar PV research. The experts were asked to identify technologies with the potential for significant advances and breakthroughs. Rather than identifying and assessing prospects for very specific individual technologies, we considered the main funding areas for such research, cognizant of the fact that in each area there are

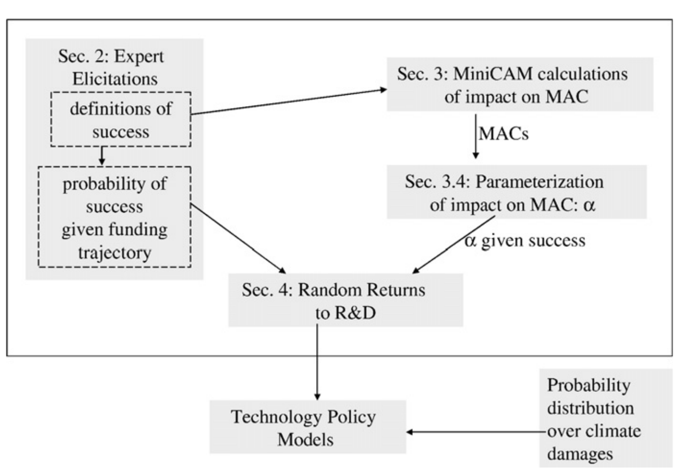

Fig. 1. A schematic representation of the flow of data in the framework. The elements inside the box are explicitly discussed in this paper.