**LITERATURE SURVEY  
 Introduction:**

As concern over climate change garners attention the question of whether it is happening gives way to what policymakers should do about it. The question of policy is an economic one. This research is necessary because climate change, left unchecked, threatens to permanently change our environment.

In Economic terms, CO2 emissions would be described as an externality. The industries that produce the pollutant do not pay for the damages they inflict on the environment. Economists have deliberated on such externalities before. In a classic experiment, Plott argued that policy measures to internalize these externalities were necessary. That is, policies that include the cost of pollution in the economic decisions made by firms and consumers should be enacted. His reasoning, and experimental results, suggested that mere concern over the welfare of others is not sufficient to protect society from environmental damages (1983).

Plott, however, did not consider a further complication of environmental economics. A politically attractive solution to climate change is to support research and development (R&D) as an answer to climate change. The studies I consider here will consider this question in conjunction with methods of internalizing climate change externalities.

**The Economics of Emissions Control:**

Previous literature reviews exist for the economics of emissions control and so this section will be a summary discussion of them. The focus of this paper is the relationship between emissions control measures and emissions R&D. For a more extended discussion of environmental experimental economics see Noussair and Soest (2014), and Friesen and Gangadharan (2013). Emissions control can be achieved through either a carbon tax or a capand-trade approach. There is some dispute over which is socially preferable and how to implement either. The trade-offs are that cap-and-trade generally requires less action on the part of the government and allows for control over the quantity of emissions, while a carbon tax is the more price stable alternative (Congressional Budget Office, 2008).

Because of the relative price stability of a carbon tax the Congressional Budget Office argues it is more efficient for the United States’ purposes than a cap and trade program (2008). They argue that there are rising marginal costs to reducing emissions as firms use the cheapest ways to reduce emissions first. But the marginal benefit of having less emissions remains constant. In other words, a cheaply eliminated unit of emissions has the same effect on climate change as does a more costly eliminated one. A cap-and-trade program would be inflexible in its response to these rising marginal costs, while a tax would not be. These issues are, however, only tangentially related to the relationship between emissions-saving policy of either kind and their effects on R&D. Both seek to address only one of the two salient market failures.

The environmental market failure has been described in terms of an externality already. But R&D is associated with positive externalities as well. Addressing both externalities is considered the dominant strategy in the literature. For example, though there is substantial support for the development of emissions-saving technology in Europe (Bye & Jacobsen, 2011), R&D in the absence of environmental policies against pollution is likely to be below the socially optimal level (Jaffe, Newell, & Stavins, 2005).

Besides being politically expedient, emissions-saving R&D has an economic argument for its support instead of emissions reducing technology (Jaffe, Newell, & Stavins, 2005). If an effective carbon-abatement technology could be produced emissions reduction would be unnecessary. Yet this is unlikely as R&D is a product of investment and subject to two significant externalities. First, without emissions reducing policy, emissions-saving R&D would be unprofitable for any given firm. Secondly, R&D is subject to the externalities described by Romer in the following section.

**Theoretical R&D Background: Endogenous Technological Change:**

A typical macroeconomics textbook will present a growth accounting equation in which the total output of the economy depends on factors like capital, labor, and productivity inputs. While the factors in my textbook that drive capital and labor growth get their own chapters endogenous growth theory, the study of factors that drive productivity growth, gets three pages (Abel, Bernanke, & Croushore, 2011, p. 206, 228-231). The disparity is not particularly surprising. Modeling endogenous growth is difficult, and challenges core macroeconomic assumptions. When Romer uses this model he explains that “price-taking competition cannot be supported” and so instead he finds an equilibrium under monopolistic competition (1989).

The conclusion Romer comes to which is of most interest is that too little human capital will be devoted to R&D in equilibrium. The theory is that this is because oftentimes the product of R&D is excludable, but nonrival. With R&D, this is often called knowledge spillovers. That is, using the patent system, a good produced by one firm’s research can be excluded from another, but the second firm’s consumption of that good does not rival the initial producer’s consumption of it. Because of this nonrival consumption knowledge spillovers are created. It follows from this that in perfect competition no private firm will participate in R&D. After all, there is nothing stopping the firm’s many competitors from stealing their research and thus matching their costs. When this happens, the researching firm has only the costs of research and no benefits from it. This is the reason the Solow model takes productivity as exogenous (Romer, 1989, p. 7).

Because of this market failure and environmental market failures, Jaffe et al. argue for a “portfolio of public policies that foster emissions reduction as well as the development and adoption of environmentally beneficial technology” (2005, p. 1). Adding the environment into the picture, however, complicates the picture of R&D spillovers somewhat:

This means that a specified level of environmental cleanup can be achieved at lower total cost to society, and it also means that a lower total level of pollution can be attained more efficiently than would be expected if the cost of cleanup were higher. Thus, in this simple static picture, technology improvements can be good for the environment and good for the firm that must meet environmental mandates. (Jaffe, Newell, & Stavins, 2005, p. 166)

Thus there is a dynamic relationship between technology and environmental protection. Given that there is an interplay between R&D and emissions policy, it may be advantageous for a country to incentivize emissions-saving R&D in particular. In fact, this is exactly the question Bye and Jacobsen as well as Schneider and Goulder consider, as I describe in the following section.

Jaffe et al. break up the externalities associated with emissions R&D into knowledge and adoption externalities (2005). The knowledge spillovers are as they are described by Romer. The adoption externalities, however, may also have dynamic increasing returns. This stems from the fact that a technology diffuses gradually. Simply observing another firm using a new piece of technology can create a positive externality as the observer may become convinced that the technology is superior and subsequently reaps some benefit from it. There are also network externalities. Some technologies become more valuable as more people use them. Finally, there are “learning-by-doing” supply-side externalities. This refers to the fact that some technologies become easier to use with experience of using them. Together, these externalities mean almost all environmental economists recommend a combination of emissions-saving subsidies of some kind and emissions-reducing taxes or cap-and-trade policies. An early General Equilibrium Model employed by Schneider and Goulder makes just this argument (1997).

**Conclusion:**

Proper execution of emissions-saving policy is nontrivial. Australia has recently made this quite evident. Robson writes that “Australia's carbon tax experience is an interesting case study in how not to go about implementing climate change policy” (2014, p. 43). And while R&D is a politically expedient answer to climate change legislation, the evidence does not support it being used alone. In Australia’s case, carbon permits were enacted on top of and in addition to new “complementary” emissions saving policies. The net effect of these changes were to increase energy prices, not reduce emissions, and damaged the government’s revenues (Robson, 2014). While action is needed, climate science must not be the only research consulted in making these decisions.

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While the GEM has attractive features about it, a laboratory experiment allows for less assumptions than does a model which purports to simulate an entire economy. It has the additional benefit of circumventing criticism of the assumption that people are rational decisionmakers by using actual people to make rational decisions. Such an experiment may also be able to incorporate the effects of political and technological uncertainty into the model. Such research is pressing since, as Schneider and Goulder point out, the costs of emissions control increase with time (1997).