# Cost Effectiveness of Alternative Policies to Induce Investment in Cellulosic Biofuels

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Over the past few years cellulosic biofuel production has continually fell short of the mandates set by the Renewable fuel standard. This has continued to happen despite positive predictions in the net present value of a cellulosic biofuel plants and government subsidy/assistance programs. The present study evaluates the impact of alternative policy instruments on the price that firms require to enter the market. Some policies aim at increasing the mean returns on investment without affecting uncertainty (annual subsidy and establishment cost subsidy), others are designed to reduce uncertainty without affecting the mean (long-term production contracts), and finally some instruments affect both (blending mandates and price supports). Results from a parameterized real options model analyzing and comparing the cost effectiveness of different policies show, on a per dollar basis, that not all policies are created equal when it comes to lowering the price premium required for entry into the industry. Our analysis finds that a biofuel price support constitute the most cost-effective policy option.

**Motivation**

Over the past decade, the United States has increasingly pushed for the development of economical forms of renewable fuels. This is due to increased concerns over climate change, energy security, and the desire for domestic job creation. Biofuels in particular, and lately cellulosic biofuels, have received a large amount of attention due to their potential benefits in addressing these problems. There have been numerous government programs implemented and proposed to induce investment into this industry (Tyner, 2010). Despite this support, cellulosic biofuel production remains well below the mandate set by the Renewable Fuel Standard. In 2013, cellulosic biofuel production totaled six million gallons. This falls 994 million gallons below the target goal of 1 billion gallons set by the Renewable Fuel Standard (EIA 2013).

Budget strains have forced the federal government to seek ways to reduce the federal deficit which has translated into proposals to cut biofuel assistance programs. Within this new environment, government's focus will turn, more than ever, to the cost effectiveness of alternative instruments. Calculating the most cost-effective programs should inform policy makers on how to induce the highest investment into cellulosic biofuel production at the lowest possible cost to the government.

**Hypothesis**

It has been argued elsewhere (Tyner, 2010; Wyman, 2007; Gonzalez et al., 2012) that despite positive predictions on the returns associated with the construction of a cellulosic biofuel plant, firms have been holding off on investing due to uncertainty that is inherent within the market. These uncertainties can come in the form of selling price, input cost, tax rate, changing technology, and government policy (Schmitt et al., 2011; Dal-Mas et al., 2011; Brown et al., 2013; Taheripour and Tyner, 2008). It is possible to calculate how uncertainty affects the trigger price for entry and exit into the second-generation biofuel industry by using a real options analysis (Dixit and Pindyck, 1993). Developing such a framework allows for quantification of the effect of different policy instruments on trigger prices. Though necessary for a thorough analysis of policy cost-effectiveness, no economic assessment of the link between competing policies and trigger prices can be found in the specialized literature. This paper fills this gap by quantifying the cost effectiveness of alternative policy instruments. In this context, we define cost effectiveness as the reduction in entry price achieved by a certain policy per dollar invested (i.e. paid as subsidy by the government or economic surplus forgone by the private sector).

**Methodology and Data**

This study finds the trigger prices for entry and exit for a cellulosic drop in biofuel plant by using a real options analysis; the trigger prices are initially calculated without any government intervention. Different policies are then modeled into the real options analysis and their impact on entry price premium and overall welfare is depicted. Government programs used to induce investment into the cellulosic biofuel industry fall into one of two main categories. They can increase the expected return or they can reduce uncertainty. A constant annual subsidy, establishment cost subsidy, and the Renewable Identification Number system are examples of the former. A long-term contract and insurance are examples of the latter. This paper models all of these programs individually. A constant annual subsidy raises the mean expected price of biofuel while keeping the variability the same. An establishment cost subsidy lowers the start-up cost of a plant while keeping expected price and variability the same. A renewable fuel standard (when implemented and not waived) raises both the effective price and lowers the variability by diminishing the tail end (low biofuel price) of the distribution. In other words if prices are low less cellulosic biofuel producers will be producing, but the RIN they receive will be higher. A long-term contract keeps the expected price of biofuel the same but it lowers the uncertainty since part of future prices are guaranteed and not subject to fluctuations. Government price insurance (or biofuel price support) primarily affects variability since it guarantees a minimum selling price. This truncation of the price distribution also increases the mean price.

Drop-in biofuels considered here are perfect substitutes to regular gasoline. Therefore, the price of drop-in biofuels, in the absence of policies, is expected to be equal to the real wholesale price of gasoline. Specification tests suggest that a geometric Brownian motion process is a more appropriate representation of the evolution of this stochastic variable so this is our specification of choice. Parameters of the Brownian motion process are estimated based on monthly historical gasoline rack prices in the Midwest during the period 1994-2013. Expressions of trigger prices for entry, mothballing, reactivation, and exit are depicted. Numerical solutions of four value matching conditions and four smooth pasting conditions were conducted with Matlab under each policy instrument (including no policy). Specifications for a plants fixed and operating costs come from Brown and Brown (2013) and feedstock costs are estimated as the average of six different predictions (Gallagher et al., 2003; Fiegel et al., 2012; Brechil et al., 2011; Perrin et al., 2011; Brown et al., 2013; Gonzalez et al., 2012). Policies considered are those discussed in Tyner et al., 2010.

**Results**

The most cost effective of these policies was the insurance policy or price support. By truncating the lower tail of the price distribution, this policy increases the mean and reduces the volatility of expected profitability resulting in significant reduction of the entry price. The fixed cost and establishment cost subsidy where the least efficient. A blending mandate falls in between because, while it costs little to the government, it will pass a higher burden onto the consumer. These results suggest that reducing uncertainty may be a more cost-effective avenue to induce entry into the cellulosic biofuel industry than increasing the mean of the biofuel price distribution through a fixed subsidy on price.

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