# IS THE SUBSIDY FOR BIOFUELS THE WAY TO GO?

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*Abstract:* This paper examines the biofuel industry in Canada and US from a trade perspective. The development of a large market for biofuel is judged to have two main benefits for North America: a reduction of Greenhouse Gas Emissions (GHG) for Canada, while the U.S. is interested in reducing the dependence on imported oil from economically and politically volatile areas. A theoretical model is developed using option value theory to determine whether the same governmental policy (subsidization) can lead to different levels of optimal subsidies in each country, where the subsidy policy is driven by two distinct motivating factors: energy security and environmental commitments. Note that if the level of subsidies for the development of biofuels industry in the two countries differs considerably, the likelihood of a trade dispute arising increases.

1.1 Introduction

In the current interdependent global energy complex, countries face critical decisions regarding both climate change mitigation and energy security. Agriculture will likely play a role both in reducing greenhouse gas emissions (GHG) and dependence on imported oil from economically and politically volatile areas since a range of crops can be used as inputs for the production of biofuel substitutes for petroleum. In addition to these two main benefits, there is a hope that a vibrant biofuel industry will contribute to rural development by creating new markets for agricultural commodities, expanding employment in the rural sector and increasing farm income.

In light of these developments, governments around the world are supporting the establishment of a biofuels industry. Biofuel production is expanding rapidly and it is at varying levels of development in different countries. In addition, governments heavily subsidize the industry since at the current level of industry development and historic fossil fuel price levels, the

cost of biofuels is still considerably greater than fossil fuel alternatives. In North America, the US and Canada possess very different motivations with respect to biofuel development. For the US, the key factor appears to be energy security, whereas within Canada increased use of biofuels is directly related to possible post-Kyoto commitments. Given these very different motivations, the optimal level of subsidies will likely be different in the two countries. This situation has the potential to create international trade frictions in the future.

If we assume that subsidizing the development of the biofuel industry in the present is equivalent to buying an option on its use for future objectives – energy security or reduced GHG emissions – an economic model can be developed to examine whether or not the same government policy (subsidization) will yield different results (different level of subsidies) if the option is based on different current period objectives. The theoretical model is developed using financial option value theory, while optimal levels of energy subsidy will be generated using numerical simulations in future research. The possibility of trade problems and trade disputes over this issue are also analyzed within the framework of current international trade law.

The paper is organized as follows: in Section II, the characteristics of biofuel industry are presented with respect to the industries in Canada and US. In Section III, we conduct a brief literature review of option theory, while the next section illustrates the results. The paper will end with trade and policy implications and some concluding remarks.

## 1.2. Ethanol Market

Fuel ethanol is a high octane, water-free alcohol produced from any biological feedstock that contains sugar, or any materials that can be converted into sugar (starch, cellulose). The two main advantages of using ethanol are that it can reduce the dependence on imports of foreign oil and it has environmental benefits, including reduction of greenhouse gases and ground level ozone (Table 1.1). Other secondary advantages of ethanol are that it is completely biodegradable

and it is based on renewable resources. Finally, it can foster rural development and increase farm incomes.

At present, the major disadvantage of ethanol is its high production cost. Without being highly subsidized, an ethanol sector would not exist. Even with a high level of support from federal and state/provincial governments, the cost of ethanol is higher than the price of gasoline. An USDA producers' survey regarding the cost of production for ethanol showed that total operating costs in 2002 had changed only slightly from 1998 (from 95.16 US cents/gallon in 1998 to 95.74 US cents/gallon in 2002). Regarding capital expenditure, new plant construction costs ranged from 1.05 US $/gallon to 3.00 US$/gallon, while average costs to expand existing ethanol production capacity was 50 US cents/gallon. Thus, the total cost of production for ethanol in the US in 2002 ranged between 1.4574 US $/gallon and 3.9574 US $/gallon (Shapouri & Gallagher, 2005). Simply put, ethanol produced from a grain feedstock using conventional conversion processes is not likely to compete with gasoline unless the world oil price rises considerably. Other secondary disadvantages are: its high volatility - limiting its use in hot weather; it has a lower energy content per litre than gasoline and; it has the potential to impair engine operation and generate corrosion in fuel system components in the case of phase separation[1].

There are varying estimates of the potential energy and GHG emissions impacts of ethanol. Assumptions pertaining to overall fuel production process efficiency, the type of process energy used, estimates of vehicle fuel economy, the types of GHG considered, land use, etc. differ (Table 1.2).

Niven (2005) reviews the literature on the environmental impact of ethanol and he determined that E10[2] reduces GHG emissions only slightly, by 1% to 5%, when the complete fuel life-cycle is considered, including ethanol production, transportation and combustion. Even E10

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[1] The phase separation can occur if excessive water is absorbed by ethanol. The result would be a mixture of alcohol and water in the bottom of a fuel tank.
[2] Fuel ethanol can be used by itself as a fuel, but, normally, it is blended with gasoline in concentrations of 5, 10 up to 85 percent (commonly known as gasohol). The most common blend contains 10 percent ethanol (E10).

is slightly more environmentally friendly than pure gasoline, its reduced energy content leads to increased consumption of fuel, which results in an overall increase in GHG emissions. He points out as well that the choice of feedstock does not have an important impact on emission reductions. However, for E20, the GHG emission reductions are between 2% and 11%, while for E85, the reduction is substantial from 19% to 70%. Niven's (2005) review also suggests that ethanol production increases the risk of soil and groundwater contamination and the production of smog.

The net energy value of ethanol (NEV) is calculated as "its fuel energy minus the energy used for its production and transportation" (Niven, 2005, 11). Thus, Niven (2005) presents the results regarding the NEV of different studies sourced mainly from the US and predominantly for ethanol produced from corn (Figure 1.1). Several studies have suggested that the energy balance is negative, with an upward trend of NEV over time, which might be the result of different assumptions or an improvement in the ethanol manufacturing process over time.

In the US, the primary feedstock for ethanol is corn. As of January 2010, there were 189 ethanol plants in the US and other 11 under construction, with most of them concentrated in the Midwest states (RFA, n.d.). Production of ethanol increased from 175 millions gallons in 1980 to 10.7 billion gallons in 2009 (RFA, n.d.). The increase in production can be explained by the high level of support offered by the US federal and state governments for the development of the industry, as well as through the total or partial ban on the use of MTBE (methyl tertiary-butyl ether) as a gasoline additive in 25 states (it is to be phase out at the federal level by 2014). Through the Energy Policy Act of 2005, programs and policies were created that are intended to increase and diversify domestic energy production. The 2005 Act includes a renewable fuels standard (RFS) provision, which requires a minimum amount of renewable fuel each year. This starts at 4 billion gallons in 2006, reaching 7.5 billion gallons in 2012 and 36 billion by 2022 (Rudaheranwa, 2009).

Currently, in the US there is a federal tax exemption of 5.1 cents per US gallon (1.34 cents/litre) for ethanol/gasoline blends that are 10 percent ethanol. For lower ethanol blends, the tax exemption is reduced proportionally. In 1998, the Federal tax exemption was 5.4 US cents per blended gallon and it was extended until 2008, but was reduced to 5.3 US cents per blended gallon in 2001, to 5.2 US cents in 2004 and 5.1 US cents in 2005. The tax exemption of 5.1 US cents per blended gallon was subsequently extended until December 2010. In addition to the subsidies that the government provides for biofuels, producers are protected from foreign competition through tariffs. Thus, the US ad valorem tariff is 2.5% of the product value plus 54 US cents per gallon as a secondary duty (RFA, 2005). The secondary duty primarily targets imports of Brazilian ethanol (Olfert & Weseen, 2007).

In addition to the federal tax exemption, at least 30 US states have decided to subsidize the ethanol industry in different ways. The incentive for ethanol production ranges from 5 US cents/gallon to 30 US cents/gallon. Several states have ethanol consumption mandates (Olfert & Weseen, 2007). Another mechanism is to offer an exemption from gasoline taxes when a blended product is sold. Direct subsidies to the producers of ethanol are also used. In addition, some states provide low-interest loans and require government vehicles to use ethanol. Total subsidies for ethanol production in the US amount to US $2.5 billion per year (Olfert & Weseen, 2007). Differing reasons for providing subsidies to the ethanol industry are provided by state governments (i.e. rural development, supporting prices etc). These state level motivations differ from the principal rationale of the US government with respect to subsidizing the biofuels industry – energy security.

According to the US Energy Information Administration (EIA), US dependency on foreign oil is estimated to grow from 62% in 2002 to more than 77% by 2025. While biofuels cannot eliminate US oil dependence anytime soon (by an estimated 1.6 million barrels by 2012), the increasing production of biofuels would reduce this dependence and improve the ability to respond to oil supply disruptions (Renewable Fuel Association, 2004 – RFA).

In Canada, the development of the fuel ethanol industry has been far slower than in Brazil or the US. In Canada, ethanol is obtained from corn (73%), wheat (17%), barley (3%) and agricultural and forestry waste (7%).

Canada is a net exporter of petroleum based fuels and, as a result, does not have an energy security motivation for promoting biofuels. In December 2002, however, the Government of Canada ratified the Kyoto Protocol. Under Kyoto, Canada agreed to a GHG emissions reduction target of 6 percent below 1990 levels during the period 2008 to 2012. This meant Canada was committed to reduce 240 megatons of GHG emissions (Figure 1.2). In order to reduce GHG emissions, the government planned to increase the production and consumption of ethanol. While the Kyoto targets will not be met, the federal government supports the development of the ethanol industry through a variety of measures (Climate Change Saskatchewan).

The measures include R&D programs for market development of technologies; $0.10 CAD/litre tax exemption for the ethanol portion of blended gasoline; the use of ethanol by federal government vehicles and Future Fuels initiatives, with an increase of 750 million litres in Canada's annual capacity to produce ethanol, yielding a 25% increase of Canada's total gasoline supply containing 10% ethanol. Another major initiative of the federal government is the Ethanol Expansion Program (EEP) that was initiated in August 2003. The EEP program supports the development of the ethanol industry in different ways: $140 million as contingent loan guarantees, $100 million as direct financing to production facilities, $3 million for public awareness and mandated usage (Klein et al., 2004). The federal government encouraged the farmers' participation in ethanol production with $200 million under the Capital Formation Assistance Program and it invested in R&D $145 million under the Agricultural Bioproducts Innovation Program, both initiated in 2006. Also, the 2007 Federal Budget allocated $2 billion over 7 years to support biofuels production, the 2008 Federal Budget gave $10 million over 2 years for R&D on biofuels emissions, while the 2009 federal budget allocated 1 billion for clean

energy R&D and demonstration projects. Except the support for the producers, the federal government implemented a consumption mandate of 5% renewable content (ethanol) by 2010. The domestic producers are protected against the ethanol imports by a tariff of 19 US cents per gallon (RFA, 2005).

As Table 1.3 shows, most of ethanol is produced in Ontario and Saskatchewan. As of April 2009, the total Canadian production capacity is 1,338 million litres ethanol, which is expected to increase to 2,266 by 2012.

Provincial support in Canada depends on the goals of each province. For instance, Saskatchewan and Manitoba are interested in developing their rural economies, while British Columbia wants to stimulate the production of cellulose-based ethanol using forest wastes. Alberta, on the other hand, has shown little interest in the ethanol industry due to the size of the provincial petroleum reserves (Klein et al., 2004). Thus, not all Canadian provinces have reductions of GHG emissions as an objective for providing support to the biofuel industry. Except for the fuel tax exemptions at the provincial level outlined in Table 1.4, the provincial governments support the development of the industry through mandated usage regulations and financial contributions for ethanol start-ups (Table 1.5).

However, in 2006, the then new conservative government realized that Canada would not able to respect its Kyoto commitments and, in fact, Canada's GHG emissions are nearly 33% above 1990 levels. In absolute terms, Canada emits approximately 747 Mt $CO_2$ per year and the Kyoto commitment would see this capped at 596Mt (Figure 1.3) (Environment Canada, 2007).

Subsequently, the federal government came up with a "made-in-Canada" approach to reduce emissions (CAD $2 billion over 5 years), which includes Canada's Clean Air Act (CCAA). Among other initiatives, the CCAA regulates the blending of fuels, which represents a step towards meeting the 5% renewable fuel content in motor fuels by 2010. The CCAA does not have short-term commitments, but the long-term one is an absolute reduction in GHG of between 45-65% from 2003 levels by 2050.

In sum, the basic arguments used to justify a high level of governmental support for the development of an ethanol sector in Canada are, first of all, environmental targets that need to be achieved and, second, rural development and the need for new markets for agricultural products.

1.3 Investment strategies and real options

Under certainty, there is no option value. Thus, a decision to invest can be made based on a simple Net Present Value (NPV) rule - invest when the present discounted value of the investment is greater than or equal to the investment cost. Traditional valuation methods in capital budgeting, such as NPV and other discounted cash flow (DCF) techniques, are premised on value maximization in a world without uncertainty and flexibility.

In reality, however, investment decisions have three important characteristics that fall outside the DCF framework (Dixit & Pindyck, 1994). Investments are often partially or completely irreversible; the cost of investment is partially sunk; investments are often undertaken under uncertainty over the future rewards; and investments can typically be postponed until more information is obtained. The latter means that even a project with a negative NPV can be valuable as long as the investment can be postponed and new favorable information can arrive.

1.3.1 Real options and financial options

By definition, a financial option gives the owner the right, but not the obligation to sell (put option) or to purchase (call option) a security at a specified price (strike price) during a specified period of time. The seminal work of Black and Scholes (1973) first analyzed the valuation of financial options. The Black-Scholes formula prices an European put or call option (meaning the option can be exercised only on the expiration date) on a stock that does not pay a dividend, and Black-Scholes assumes that the stock price follows a geometric Brownian motion[3]

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[3] Dixit and Pindyck (1994)

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with constant volatility. One other important assumption of this model is that the underlying asset is tradable, allowing for the use of risk-neutral valuation.

Subsequent research has shown that the same basic definition of an option can be applied to other situations that do not involve the use of a financial asset. Thus, a firm that has the opportunity to invest holds an option, which is similar to a financial option. It possesses the right, but does not have an obligation to buy or sell an asset at some future time. When firms make an irreversible investment, they give up the possibility of waiting for new information, which might affect the desirability and timing of the expenditure. This lost option is an opportunity cost that should be included in the cost of investment.

Such non-financial options are called "real options", stressing the strong link with the financial options (Figure 1.4). The value of a real option increases as the stock price (S), time to expiration (t), risk-free rate of return ($r_f$) and variance of returns ($\sigma^2$) increase, and the exercise price (X) decreases.

As discounted-cash-flow (DCF) approaches (e.g. NPV) applied in investment projects cannot capture the value of management having the flexibility to revise decisions according to the changes and uncertainty that characterize the marketplace, returns from the projects will most probably differ from what management expected. As new information arrives, management should be able to adapt to the conditions and to react accordingly to minimize losses, so managerial flexibility in this manner is very important in an investment. Trigeorgis (1993) defines managerial flexibility as a collection of real options - the option to defer, to abandon, to contract, to expand or to switch the investment.

1.3.2 Literature review

Option value theory has led to a rich literature pertaining to empirical applications that analyze investment opportunities. The investment problem studied here can be included in a category of real options referred to by Trigeorgis (2001) as a time to build option (staged

investment). This is important for R&D intensive industries and long-development capital-intensive projects. The development of a new industry (e.g. the biofuel sector) has the following three characteristics: 1) decisions and cash outlays take place sequentially over time; 2) there is a maximum rate of investment; and 3) there are no returns until the project is completed (Majd & Pindyck, 1987).

This work builds on several related studies in the real options literature. Roberts and Weitzman (1981) constructed a model of a "sequential development project" (SDP) which has the same features outlined above. By their definition, the project can be stopped in any stage and as the investment takes place, the cost of completing the project and its uncertainty (variance) are reduced. These authors derive an optimal sequential decision rule for R&D or exploration projects and they show that even if NPV is negative, the investor should go ahead with the first stages of the project. Weitzman, Newey and Rabin (1981) apply the sequential methodology to examine whether the development of liquid synthetic fuels from the coal market should be subsidized by the US government. McDonald and Siegel (1986) considered a basic model of irreversible investment with two stochastic variables, each of which evolves in geometric Brownian motion - the sunk cost and the value of the project. Their results show that the optimal investment in this case is reached by waiting until the benefits are twice the investment cost.

Majd and Pindyck (1987) determine an optimal investment rule for a sequential investment, when a firm can invest at a maximum rate, and the value of the project follows geometric Brownian motion. An important characteristic of their model is that expenditure flow can be adjusted as new information arrives. They show that the largest effects of time to build appear when uncertainty is very high, the opportunity cost of delay is high and when the maximum rate of investment is low.

Emery and McKenzie (1996) evaluated the subsidy granted to the Canadian Pacific Railway (CPR) from an "ex ante" perspective. They considered that the "ex post" studies that concluded that the subsidy was too large are limited by ignoring the uncertainty that existed at

that time. They employed a real option approach to see the importance of timing in "once-and-for-all" investment decisions in an uncertain environment. They concluded that the "ex-ante" value of the subsidy is lower than the required level that it is necessary to compensate the company for forgoing its investment options and, also, the value of the subsidy is lower as the income stream becomes riskier.

Finally, Schwartz and Moon (2000) analyzed investment in R&D (the development of a new drug) considering three sources of uncertainty - uncertainty about investment cost, future payoffs and the possibility that a catastrophic event can stop the project. Their findings describe not only the value of the project, but also the optimal values for the state variables at which the investment should proceed.

The study that has inspired this research is "Investments of uncertain cost" by Robert S. Pindick in 1993. Pindyck (1993) exploited the same idea as in Majd and Pindyck (1987) with the exception that the cost of completing the project is uncertain as opposed to the value of the project. An extension of the paper considers the situation where both, the value of the project and the cost of investment, are characterized by uncertainty. Except for the uncertain cost, the investment is also considered irreversible, meaning that the investment cost is sunk.

1.4 A Real Option Model of Biofuel Investment by Government

To our knowledge, there is only one prior study, Emery and McKenzie (1996), which uses a real option valuation model to assess a governmental policy. Their study is more simplistic, as they consider uncertainty only over the investment's future returns. Further, existing environmental policy analyses study the behavior of firms in those cases when investments have environmental benefits.

To start, a subsidy for the biofuel industry is considered as a normal investment that is undertaken by the government, and not by a firm. The goal of government in this case is to maximize the investment value of the project. We note that we do not consider any benefits that

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agricultural support programs could bring to producers and consumers through increased crop prices or employment. Therefore, this model will capture only the primary motives sought after by respective governments - environmental benefits (Canada) and decreased energy dependence (the US).

At a given period of time, the value of government investment is measured by the increase in the project value due to the new investment. Assuming that without subsidy there will be no market for biofuels, the investment value associated with the biofuel industry in the case of no subsidy will be 0. The investment value would appear as in Eq. 1.1.

$$V(I) = P*Q - wx - \tilde{S} + O*y + D(y)^4 \tag{1.1}$$

where,

V(I) = investment value in a certain time period;

P = the price of biofuels without subsidy;

Q = the quantity consumed of biofuels;

w = per unit cost of inputs;

x = input quantity used in producing the biofuels;

$\tilde{S}$ = the total subsidy used by governments to help the industry;

O = the unit price of oil;

y = the quantity of oil that is replaced by biofuels;

D = environmental benefit function.

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[4] The model is kept simple to show the main focus of our study, the subsidy. The model can be explained as a simple investment problem at a specific point in time, t. Before the market started to be subsidized, the costs of investment would be greater than the revenues (obtained from selling the biofuels) and without intervention, the market would not develop. Thus, the government intervenes with the subsidy, which will make the net revenues positive. Environmental and energy security benefits are secondary effects of the subsidy.

1.4.1 Variables' description

We assume here that P and Q are uncertain. By developing the biofuels market, in the future, the price of biofuels would decrease, while the quantity consumed would increase. Since prices cannot be negative, we let P follow a process of geometric Brownian motion with drift to reflect stochastic innovations as well as any long-term trend in price evolution:

$$dP(t) = \alpha_P P(t)dt + \sigma_P P(t)dz_P(t) \tag{1.2}$$

where $dz_P$ is the increment of a Wiener process: $dz_P = \varepsilon\sqrt{dt}, \varepsilon \sim N(0,1)$; $\alpha_P$ is the drift parameter, which represents the rate of growth, and $\sigma_P$ is the volatility in the drift parameter.

Q also follows a process of geometric Brownian motion to reflect stochastic innovations:

$$dQ(t) = \alpha_Q Q(t)dt + \sigma_Q Q(t)dz_Q(t) \tag{1.3}$$

The parameter $\alpha_Q$ is the expected rate of demand growth, while $\sigma_Q$ is the standard deviation of the expected percentage change in demand. The variable $dz_Q$ is a standard Wiener process with zero mean and standard deviation of $dt$. The relationship between Q and P is reflected in $E[dz_P dz_Q] = \rho_{PQ}dt$, where $-1 \le \rho_{PQ} \le 0$ is the instantaneous correlation between Q and P. Clearly, negative correlation implies a downward sloping demand curve.

The cost of investment, represented by the subsidy $\tilde{S}$, is considered uncertain as well.

Uncertainty of $\tilde{S}$ can be justified by the fact that developing an energy market is a large project that takes considerable time. On top of being an uncertain cost, this kind of investment is also irreversible. For various reasons, such as insufficient demand for the product or excessive costs, the government cannot recover the money spent on trying to develop the ethanol market.

As developed here, the uncertainty in project costs is called technical uncertainty (Pindyck, 1993). Technical uncertainty is related to the physical difficulty of completing the project, including both time and effort. In fact, the total cost of the project can be known only

when it is completed. There is no value of waiting in this case, as all the information about cost

arrives as the investment takes place.

Next, following the investment model of Pindick (1993) we consider the expected cost of

completing the project $S = E(\tilde{S})$. Changes in the expected cost of investment S are captured

using the following controlled diffusion process:

$$dS = -Idt + \sigma_S ( IS )^{1/2} dz_S \qquad (1.4)$$

where I represents the rate of investment, and $dz_S$ is a Wiener process. Note in Eq. (1.4) the

expected cost to completion declines with the rate of investment, and also changes stochastically.

This functional form for expected cost is very easy to manipulate and yields just two solutions -

no investment or investment at the maximum rate $I_m$. Notice that if I=0, dS=0 and there is no

technical uncertainty over the level of S required to develop the market. The stochastic term in

Eq. (1.4) has a mean of 0, meaning that the expected level of S is unbiased. According to Pindyck

(1993), the variance of S is:

$$\sigma_S^2( S ) = \left( \frac{\sigma_S^2}{2 - \sigma_S^2} \right) S^2 \qquad (1.5)$$

Eq. (1.5) shows that as S decreases, uncertainty in S decreases, which reflects a process of

learning with investment.

Further, the revenue obtained by replacing the imported oil with the biofuels: y*O, is

considered here to be a benefit. The future price of oil, O, is a stochastic variable that can be

represented either by a simple random walk with a mean reversion or by a random walk with

mean reversion and a jump process. We offer that the mean-reversion process is the natural

choice for modeling oil price. Even though oil price suffers short-term shocks, historically it has

tended to revert back to a normal long-term equilibrium.

On that note, the simplest mean-reverting process known also as Geometric Ornstein-

Uhlenbeck or Dixit and Pindyck model (Dixit & Pindyck, 1994) is:

$$\frac{dO}{O} = \eta\left(\bar{O} - O\right)dt + \sigma_O dz_O \tag{1.6}$$

where the first term is the mean-reverting drift, $\bar{O}$ is the long-run equilibrium mean and $\eta$ is the speed of reversion. The second term represents continuous time uncertainty, where $\sigma_O$ is the volatility, while $dz_O$ is a Wiener increment.

As biofuels are increasingly used as a substitute for oil, there may be a relationship between the price of oil and the biofuel quantity consumed. Ceteris paribus, as the price of oil increases, the quantity consumed of biofuels should increase as well. Thus, we represent the relationship between O and Q by $\rho_{OQ}$, the correlation coefficient between the two variables, with $0 \le \rho_{OQ} \le 1$.

The last term of Eq. (1.1) above is an environmental benefits function. Each unit of oil consumed produces an amount of GHG emissions. Let us assume e is the total emissions released by oil consumption, and each unit of oil consumed releases $\gamma_i$ units of GHG emissions ($CO_2$, $NO_x$, $SO_2$ etc.). It follows that: $e = y * \gamma_i$. Under this specification, a reduction in GHG emissions represents an environmental benefit for society. In our case, the environmental benefits function is equal to the product between the total reduction in GHG emissions, e, and the price per unit of GHG emissions, $\tau$ : $D(y) = e * \tau$.

As the total emission, e, is a function of the quantity of oil consumed, we consider y to be a stochastic variable. The quantity of biofuel consumed is unknown, rendering the quantity of oil that it replaces a random variable. Assuming further that y follows a Brownian motion process, this leads to the following specification for our stochastic environmental benefits function:

$$dD = \gamma_i \tau(\alpha_y y dt + \sigma_y y dz_y) \tag{1.7}$$

where $\alpha_y$ is a drift parameter, $\sigma_y$ is the volatility in the drift parameter, and once again, $dz_y$ is a Wiener process with the property that $dz_y = \varepsilon \sqrt{dt}$, $\varepsilon \sim N(0,1)$.

Also, the relationship between y and O is reflected in $E[dz_y dz_O] = \rho_{yO} dt$ where $-1 \leq \rho_{yO} \leq 0$ is the instantaneous correlation between y and O. Clearly, negative correlation implies a downward sloping demand curve for oil.

We can derive decision rules for irreversible investment knowing that total cost is technically uncertain and that the value of the investment represented by returns is stochastic. Our decision rule also accounts for the possibility that the project could be abandoned. The rule we follow here is that government will invest in developing the biofuel market as long as the expected cost of the investment is less than some specified critical value (Pindyck, 1993). Furthermore, the investment value function does not include an environmental benefits function in case of the US, while for Canada, this function does not include the benefits from imported oil replacement.

Ultimately, this problem is characterized by a compound option. It is a sequential investment problem with technical uncertainty. We have a compound option because each annual investment, I, creates a new investment option on the present value of cost savings from the investment already done, with a diminished exercise price S-I. In fact, this kind of investment program can be temporarily or permanently suspended without cost. In the following section, the optimal investment rules for the US and Canada will be found.

1.4.2 Optimal investment rules

The US case can be considered the general situation as it includes all the variables considered to be stochastic. Using the assumptions outlined above for the US, we want to estimate the value of the biofuel investment that the government will maximize. This is represented by the investment value:

$$V(I) = P(t)*Q(t) + O(t)*y(t) - w*x - \tilde{S}(t) \qquad (1.8)$$

An optimal investment rule can be found using contingent claim analysis. Note that the model has five stochastic variables: P, Q, O, y and S. The variables w and x are considered deterministic because they do not affect the value of the subsidy. Changes in each of the stochastic variables follow a geometric Brownian motion, save for the price of oil where we assume a mean-reverting process. These changes are expressed by the Eq. (1.2), (1.3), (1.6), (1.7) and (1.4). Furthermore, we assume that the risks in P, Q, O, y and S are spanned by existing assets, an assumption crucial to this method (Trigeorgis, 1993). We can make this assumption in this case since the product being developed is closely related to commodities (oil) that are usually traded on spot and future markets. So, following Dixit and Pindyck (1993), we consider a portfolio for which we hold the option to invest, and the opportunity to invest is worth F(P, Q, O, y, S). The investment opportunity F(P, Q, O, y, S) must satisfy the following stochastic differential equation:

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\begin{aligned}
\max_{I(t)} rF = &\frac{1}{2} F_{PP} \sigma_P^2 P^2 + \frac{1}{2} F_{QQ} \sigma_Q^2 Q^2 + \frac{1}{2} F_{OO} \sigma_O^2 O^2 + \frac{1}{2} F_{yy} \sigma_y^2 y^2 + \\
&+ \frac{1}{2} F_{SS} \sigma_S^2 IS + F_{PQ} \sigma_P \sigma_Q PQ \rho_{PQ} + F_{yO} \sigma_y \sigma_O yO \rho_{yO} + \\
&+ F_{OQ} \sigma_O \sigma_Q OQ \rho_{OQ} + F_P P(r - \delta_p) + F_Q Q(r - \delta_q) + \\
&+ F_O O(r - \delta_O) + F_y y(r - \delta_y) - IF_S - I
\end{aligned}
\qquad (1.9)
$$

Eq. (1.9) is similar to a Bellman equation found using stochastic dynamic programming. The only differences are that the riskless interest rate r, which is specified endogenously[5] in our model, is used in place of an exogenously specified discount rate, and the growth rate $\alpha$ of the geometric Brownian motion is replaced by $r - \delta$, where $\delta$ represents an opportunity cost of delaying the construction of the project and keeping the option to invest alive (Dixit & Pindyck, 1994). Thus, in the case of contingent claim analysis, $\mu = \alpha + \delta$ represents the total expected rate

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[5] We considered an endogenous interest rate as it represents a general situation. However, an optimal investment rule can be found using dynamic programming, subject to some exogenous discount rate.

of growth. The total expected rate of return $\mu$ represents the compensation that investors obtain

for taking risk, noting that the critical risk here is nondiversifiable risk. The rate-of-return for the

price of oil equals $\mu = \eta(\bar{O} - O) + \delta_O$.

Eq. (1.9) is linear in I, so the maximization problem gives us just two solutions:

$$I(t) = \begin{cases} I_m, \dfrac{1}{2}F_{SS}\sigma_S^2 S - F_S - 1 \geq 0 \\ 0, otherwise \end{cases} \tag{1.10}$$

Interpreting this solution, we note that government should invest as long as the expected

cost to complete the project falls below a critical value. The general solution also indicates that

the market should be developed as long as the total subsidy (the cost of the project) is less or

equal to the critical value $S^*$(P, Q, O, y). If this is the case, government should invest at the

maximum rate $I_m$. In the case where the total subsidy is greater than $S^*$(P, Q, O, y), investment

should not be undertaken. Next, the value of $S^*$ can be found as part of the solution of F(P, Q, O,

y, S). Note as well that Eq. (1.9) is an elliptic partial differential equation with a free boundary

along the space $S^*$(P, Q, O, y). To determine $S^*$(P, Q, O, y) and F(P, Q, O, y, S), we need to solve

Eq. (1.9) subject to the following boundary conditions:

$$F(P, Q, O, y, 0) = V(P, Q, O, y) \tag{1.11}$$

$$\lim_{P \to 0} F(P, Q, O, y, S) = 0 \tag{1.12}$$

$$\lim_{Q \to 0} F(P, Q, O, y, S) = 0 \tag{1.13}$$

$$\lim_{O \to 0} F(P, Q, O, y, S) = 0 \tag{1.14}$$

$$\lim_{y \to 0} F(P, Q, O, y, S) = 0 \tag{1.15}$$

$$\lim_{S \to \infty} F(P,Q,O,y,S) = 0 \tag{1.16}$$

$$\frac{1}{2} F_{SS}(S^*,P,Q,O,y)\sigma_S^2 S^* - F_S(S^*,P,Q,O,y) - 1 = 0 \tag{1.17}$$

$F(P,Q,O,y,S)$ continuous at $S^*$(P, Q, O,y) $\qquad\qquad$ (1.18)

To summarize the boundary conditions, Eq. (1.11) implies that at the end of the project, when the amount of subsidy would be 0, the payoff would be V(P, Q, O, y) – exactly the value of the project. Eq. (1.12), (1.13), (1.14) and (1.15) show that a value of 0 is the absorbing barrier for P, Q, O and y, whereas Eq. (1.16) shows that when S is very large, the probability of beginning the project in some finite time approaches 0. Eq. (1.17) is derived from Eq. (1.9) and is equivalent to the so-called "smooth pasting" condition (Pindyck, 1993) that $F_S(S^*$, P, Q, O, y) is continuous at $S^*$(P, Q, O, y). Finally, Eq. (1.18) is the "value matching" condition, meaning that F(P, Q, O, y, S) is continuous at $S^*$(P, Q, O, y).

Eq. (1.9) together with the boundary conditions specified above can be solved numerically using simulations. This means finding $S^*$(P, Q, O, y) and F(P, Q, O, y, S) at the same time. We do not consider the case where the investment rate is 0 as without being subsidized, the market for biofuels would not be developed.

However, related to the option value, the greater the uncertainty, the greater value of the opportunity to invest and the larger the maximum expected cost for which investing is economical. The option value is also related to the maximum investment rate $I_m$, as the maximum rate of investment is larger, the value of the investment opportunity is greater because the expected benefits are received earlier and they would be discounted less. In the same time, as the investment opportunity is worth more, the critical value of investment, S*, will be larger.

In case of Canada, the investment value that the government will maximize is expressed in the following equation:

$$V(t) = P(t)*Q(t) + D(y)(t) - w*x - \tilde{S}(t) =$$

$$= P(t)*Q(t) + y(t)*\gamma_i*\tau - w*x - \tilde{S}(t) \qquad (1.19)$$

The investment opportunity function for Canada is a special case of the one for the US, by not taking into account the price of oil[6].

$$\max_{I(t)} rF = \frac{1}{2} F_{PP} \sigma_P^2 P^2 + \frac{1}{2} F_{QQ} \sigma_Q^2 Q^2 + \frac{1}{2} F_{DD} \sigma_y^2 y^2 \gamma_i^2 \tau^2 +$$

$$+ \frac{1}{2} F_{SS} \sigma_S^2 IS + F_{PQ} \sigma_P \sigma_Q PQ \rho_{PQ} + F_P P(r - \delta_p) + F_Q Q(r - \delta_q) + \qquad (1.20)$$

$$+ F_D y \gamma_i \tau(r - \delta_d) + F_S I - I$$

In this case, the rate-of-return in each variable equals $\mu = \alpha + \delta$. Since Eq. (1.20) is linear in I, this maximization problem yields a corner solution, as follows:

$$I(t) = \begin{cases} I_m, \dfrac{1}{2} F_{SS} \sigma_S^2 S - F_S - 1 \geq 0 \\ 0, otherwise \end{cases} \qquad (1.21)$$

Not surprisingly, we obtain the same fundamental investment rule as that found for the US. The government should invest at the maximum rate $I_m$ as long as $S \leq S^*(P,Q,D)$, where $S^*$ represents a critical value of subsidy. However, the investment should not be continued if $S > S^*(P,Q,D)$. The critical value $S^*$ can be found as part of the solution of F(P, Q, D, S). Once again, Eq. (1.20) is elliptic with a free boundary along the space $S^*$(P, Q, D). The same boundary conditions together with Eq. (1.20) will help us finding $S^*$(P, Q, D) and F(P, Q, D, S).

1.4.3 Comparison of the optimal investment rules

From a theoretical point of view, the partial differential equations differ from each other because of terms related with the price of oil and the environmental function.There are only two situations when the two equations would give the same solutions for the critical values of the subsidy levels:

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[6] The steps followed in finding the objective function can be obtained by request from the authors.

a) when the total environmental damage created by the consumption of oil and the total cost of replaced oil are 0. The two terms can be 0 in the same time only when the total quantity of oil replaced by biofuels equals 0, which is equivalent with the fact that there is no consumption of biofuels. Having no consumption of biofuels, means that the revenues obtained from selling biofuels are 0.

Thus, the levels of the critical subsidies would be equal in the two countries when there is no demand for biofuels. This situation is not likely to appear, as there is no reason to continue to subsidize the market development with a zero demand for the specific product. Hence, in this situation, the critical levels of subsidies would equal 0.

b) when the terms related to the total environmental benefits in Canada equal the terms related to the total cost of replaced oil in the US. In this situation, the critical values of subsidies in the two countries are equal when the total price of GHG emissions per unit of oil consumed equals the total unit price of oil (the unit can be considered a barrel). In other words, the two levels of subsidies are the same when the price of oil internalizes the externality produced by consuming the oil.


1.5 Trade and policy implications

The spectacular increase in biofuels production in recent years leads to questions related to the possibility of trading biofuels. Based on the theoretical results obtained in this research, another important question is whether or not the levels of subsidies that governments use to help the development of the specific industry would lead to trade disputes in the near future. Thus, this section outlines the way biofuels are treated under the World Trade Organization (WTO) rules and the possible trade disputes that can arise in the future.

Before discussing the possible trade disputes that can arise in biofuel market, it is important to outline the level of trade in biofuels. Another important aspect is whether or not

there is any ground to believe that countries will be willing and will consider it advantageous to start trading biofuels.

Presently, most biofuels are produced and consumed in domestic markets. There is a limited amount of trade in biofuels - exports of ethanol from Brazil and some intra-EU trade of biodiesel (IPC & REIL, 2006). Given some of the reasons for which countries boost the production of biofuels, such as energy security, rural development and increased opportunities for agricultural commodities, it is quite obvious that the push for biofuels production is focused on domestic production and use. However, countries interested in the environmental benefits of biofuels, mostly the Kyoto signatories, might as well look for more cost-efficient producers beyond their borders. Thus, there is a potential for trade in biofuels, especially if we take into account the fact that the countries where the biofuels can be produced more efficiently and cheaper are not the same as the countries where biofuels consumption is being mandated and encouraged (IPC & REIL, 2006). Developing countries have a comparative advantage in producing biofuels due to the longer growing seasons, large areas of arable land and much lower labour costs. Some of these countries already show an interest in developing local production of biofuels, which is mostly seen as a development tool, as their markets for agricultural commodities would expand, significant rural development would take place and much of their expenditures on fossil fuels would be reduced. In the same time, developing countries are in a disadvantaged position compared to developed countries. They would never have the financial resources to offer the same government support as the biofuels industry receives in the developed countries. They have to rely on private investment, which leads to the conclusion that even if there is a great potential for trade in biofuels, there is a need for a transparent and global trading regime (IPC & REIL, 2006).

Thus, the next apparent question is how WTO treats biofuels? There are many potential trade issues that can arise when countries start trading biofuels. These are related to the level of subsidies, market access and tariff classification, different technical barriers to trade that can

occur based on the product standards and technologies used in the production of biofuels and, as well, issues related to trade in biotechnological produced biofuels (Kerr & Loppacher, 2005). However, our paper is concentrated only on the potential trade problems that can arise as a result of large levels of governmental support (subsidies) for the development of the biofuels market.

The primary problem regarding the biofuels is their definition and classification under WTO. Most of the WTO members are also members of the World Customs Organization (WCO) and they use the system of classifications developed by WCO, known as Harmonized Commodity Description and Coding System (HS). Thus, under the WTO, the tariff levels and the allowable subsidies are negotiated based on this system. Ethanol is considered an agricultural product (HS Cap. 22), being classified based on its chemical composition as undenatured (220710) and denatured (220720), but without being separately classified as ethanol used as fuel as opposed to ethanol used for other purposes. On the other side, biodiesel is considered an industrial product, being classified in HS Cap. 38. The definition of the products is a central question. The rules for industrial products specified under the WTO Subsidy and Countervailing Measures (SCM) agreement set greater constraints on the subsidy levels. The rules for agricultural products specified under the WTO Agreement on Agriculture (AoA) place fewer constraints on subsidies. Agricultural tariffs are, typically, considerably larger than non agricultural tariffs. The classification problem is getting more complicated when considering the possibility that some biofuels would be pushed to be considered environmental goods and to be subject to negotiations related to "Environmental Goods and Services". However, during Doha Round, little progress was made in these negotiations, starting with the definition of what would be considered an "environmental good" (IPC & REIL, 2006). If they are considered "energy goods", the WTO does not have specific disciplines for trade in energy as until recently, major players in energy market, such as Saudi Arabia, were not part of the agreement (Selivanova, 2006). Thus, it is commonly accepted that with some exceptions, as national security and scarce and potentially scarce commodities, energy policies are exempted from discipline (IPC & REIL, 2006). Other

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complications would arise if the US were to attempt to use the "primary" exemption in the WTO, claiming that their subsidies for biofuels have been put in place for reasons of "national security". However, this would not be claimed by other countries, such as Canada, that do not have an energy security problem.

If biofuels were to be categorized as industrial goods, the subsidies would be disciplined by the rules of the SCM agreement. SCM agreement divides the subsidies in three categories: prohibited, actionable and non-actionable (Figure 1.5).

The actionable subsidies are the ones that distort trade in the sense that they cause adverse effects to the interests of other countries that are WTO members. One basis for actionability is represented by the existence of serious prejudice to the interests of other members, meaning that the subsidized product displaces the complainant's exports from the domestic market or from a third market. One criteria for deciding whether a subsidy provoked serious prejudice to the interests of another country is the size of the subsidy, considering that when the total ad valorem subsidization of a product exceeds 5%, serious prejudice have occurred. Other criteria for actionability are represented by material injury and nullification and impairment of the benefits of bound tariff rates (WTO, 1994). The subsidies given for the biofuel industry in the US and Canada would fit the category of actionable subsidies, as they are clearly larger than 5% of the product value (Kerr & Loppacher, 2005). Thus, if biofuels were to be categorized as industrial products at the WTO and the current levels of subsidies will continue to be given to the industry and they will be administered in the same way, there is a considerable potential for trade disputes in the future.

If biofuels were to be categorized as agricultural goods, they would be governed by the WTO Agreement on Agriculture (AoA). Under AoA, the subsidies are classified in a similar fashion to industrial subsidies, but they face lower constraints and they have different definitions (Kerr & Loppacher, 2005) (Figure 1.6).

Taking into account the definition of each type of subsidy, we could conclude that the biofuel subsidies can be included in Amber box, being considered actionable subsidies. If the governments consider biofuel subsidies to be very important, they will face few constraints, as the level of the other Amber subsidies could be cut in order to make place for the biofuel subsidies within the capped level (Kerr & Loppacher, 2005).

Another issue that can arise is if the governments try to fit the biofuel subsidies in the Green box, under an environmental program. Thus, they will not be limited or actionable. However, in order to be considered payments under an environmental program, some conditions should hold. First, they have to be payments under a clearly-defined government environmental or conservation program, they have to be dependent on conforming to certain pre-specified activity norms and the payment should be limited to the extra cost or loss of income involved in complying with the government program (WTO, 1994). If the biofuel subsidies will be categorized in the Green box, two main issues can arise in a trade dispute. Firstly, there should be enough scientific evidence that environmental benefits are provided and they fit within an environmental program and, secondly, it is the question of how the extra costs are measured (Kerr & Loppacher, 2005). In a trade dispute, each country will have a different way of considering how much is "enough" scientific evidence and how the extra costs are calculated. Therefore, disputes are almost sure to arise in the near future at the WTO.

1.6 Summary and conclusions

Issues regarding climate change and energy security have led to the continued development of alternative fuels. In addition, agriculture views biofuels as a future growth area that could help save a declining industry. Thus, development of a large market for biofuel is judged to have two main benefits for North America. The first is a reduction of Greenhouse Gas Emissions (GHG) for Canada, while the U.S. will likely use subsidies to reduce dependence on imported oil from economically and politically volatile areas. Secondary advantages associated

with using biofuels are rural development and the creation of new markets for agricultural commodities, leading to new jobs in the rural sector. The main disadvantage of using biofuels at the moment is its high cost relative to petroleum. Even at current petroleum prices, a biofuel market will not grow without being highly subsidized by governments.

A theoretical real options model is developed to examine how the same governmental policy (subsidization) towards this issue under different motivation leads to various levels of optimal subsidies. The optimal biofuel subsidy in Canada is a function of price and quantity of biofuel consumed, and the quantity of oil that is replaced by biofuel. In contrast, the US optimal biofuel subsidy is a function of the same parameters along with the price of oil. The two levels of optimal subsidies per capita could be precisely quantified in future research.

Note that if the level of subsidies for the development of biofuels industry in the two countries differs considerably, the likeliness of a trade dispute arising increases. Disputes will be a function of whether the subsidies are included in the so-called "green box" or not. If they are included in the green box being used for environmental reasons, they will not be actionable or limited, so there will be no trade problems. In this case, there should be scientific evidence that environmental benefits are provided and, second, the industry is subsidized because the biofuels are not priced competitively. However, the lack of clarity in current trade law in these areas means that future trade disputes are likely to arise (Kerr & Loppacher, 2004).

Based on our theoretical model, we could conclude that the levels of the optimal subsidies would be different in general, with the exception of two situations: when there is no demand for biofuels, in which case we concluded that also the optimal subsidies would be zero, and when the price of oil internalizes the externality which is produced by the consumption of oil. In all the other situations, the optimal subsidies would be different, increasing the potential for trade problems between the two countries.

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# TABLES

Table 1.1 Emission reductions from ethanol blends

| Emission | Low-level blends (E10) | High-level blends (E85) |
|---|---|---|
| Carbon Monoxide (CO) | 25-30% decrease | 25-30% decrease |
| Carbon Dioxide ($CO_2$) | 10% decrease | up to 100% decrease |
| Nitrogen Oxides ($NO_x$) | 5% increase/decrease | up to 20% decrease |
| Volatile Organic Carbons (VOC): | | |
| Exhaust | 7% decrease | 30% or more decrease |
| Evaporative | - | Decrease |
| Sulphur Dioxide ($SO_2$) and particulate matter | Decrease | significant decrease |
| Aldehydes | 30-50% increase (but negligible due to catalytic converter) | - |
| Aromatics (Benzene and Butadiene) | Decrease | more than 50% decrease |

Source: Canadian Renewable Fuels Association

Table 1.2 Energy and GHG impacts of ethanol: estimates from corn and wheat to ethanol studies

| | Feedstock | Ethanol production efficiency (litres/tone of feedstock) | Fuel process energy efficiency (energy in/out) | Well-to-wheels GHG emissions: compared to base (gasoline) vehicle (per km traveled) | |
|---|---|---|---|---|---|
| | | | | Fraction of base vehicle | % reduction |
| GM/ANL, 2001 | Corn | 372.8 | 0.50 | n/a | n/a |
| GM/ANL, 2001 | Corn | 417.6 | 0.55 | n/a | n/a |
| Pimentel, 2001/91 | Corn | 384.8 | 1.65 | 1.30 | -30% |
| Levelton, 2000 | Corn | 470.0 | 0.67 | 0.62 | 38% |
| Wang, 2001 | Corn-dry mill | 387.7 | 0.54 | 0.68 | 32% |
| Wang, 2001 | Corn-wet mill | 372.8 | 0.57 | 0.75 | 25% |
| Levy, 1993 | Corn | 367.1 | 0.85 | 0.67 | 33% |
| Levy, 1993 | Corn | 366.4 | 0.95 | 0.70 | 30% |
| Marland, 1991 | Corn | 372.8 | 0.78 | 0.79 | 21% |
| Levington, 2000 | Wheat | 348.9 | 0.90 | 0.71 | 29% |
| ETSU, 1996 | Wheat | 346.5 | 0.98 | 0.53 | 47% |
| EC, 1994 | Wheat | 385.4 | 1.03 | 0.81 | 19% |
| Levy, 1993 | Wheat | 349.0 | 0.81 | 0.68 | 32% |
| Levy, 1993 | Wheat | 348.8 | 0.81 | 0.65 | 35% |

Table 1.3 Ethanol production in Canada (April 2009)

| Company | Town | Province | Feedstock | Capacity (million litres) |
|---|---|---|---|---|
| Permolex | Red Deer | AB | Wheat | 40 |
| Husky Energy | Lloydminster | SK | Wheat, corn | 130 |
| Terra Grain Fuels | Belle Plain | SK | Wheat | 150 |
| Poundmaker | Lanigan | SK | Wheat | 12 |
| NorAmera Bioenergy | Weyburn | SK | Wheat, corn | 25 |
| Husky Energy | Minnedosa | MB | Wheat starch | 10 |
| Husky Energy (expansion) | Minnedosa | MB | Wheat, corn | 120 |
| Iogen | Ottawa | ON | Wheat Straw | 3 |
| IGPC | Aylmer | ON | Corn | 150 |
| Greenfield Ethanol** | Hensall | ON | Corn | 145 |
| Greenfield Ethanol | Tiverton | ON | Corn | 3.5 |
| Greenfield Ethanol | Chatham | ON | Corn | 120 |
| Greenfield Ethanol | Johnstown | ON | Corn | 200 |
| Greenfield Ethanol | Varennes | QC | Corn | 120 |
| Greenfield Ethanol* | Edmonton | AB | Municipal waste | 36 |
| Collingwood Ethanol | Collingwood | ON | Corn | 50 |
| Suncor Energy | St. Clair 1 | ON | Corn | 200 |
| Suncor Energy** | St. Clair 2 | ON | Corn | 200 |
| Enerkem | Westbury | QC | Wood waste | 5 |
| North West Bio-Energy & Terminal* | Unity | SK | Wheat | 25 |
| Kawartha Ethanol* | Havelock | ON | Corn | 80 |
| Northern Ethanol* | Niagara Falls | ON | Corn | 409 |
| Northern Ethanol* | Sarnia | ON | Corn | 378 |
| Okanagan Biofuels*** | Kelowna | BC | Wheat | 114 |

* plant currently under construction
** plant on hold
*** status unknown
Source: Laan et. al (2009)

Table 1.4 Tax exemption for fuel ethanol by province

| Govt. | Provincial fuel tax exemptions (cents/litre) | Eligibility for the subsidy | Duration |
|---|---|---|---|
| AB | 9.0 | No restriction on ethanol source | 5 years after the start-up of an ethanol production plant |
| BC | 14.5 | For E85 to E100 and E5 to E25. Ethanol must be produced in BC | - |
| ON | 14.7 | No restriction on ethanol source | Until 2010 |
| SK | 15.0 | Ethanol must be produced and consumed in SK | 5 years |
| QC | 16 to 20 (under project) | Ethanol must be produced in QC | 1999-2012 |
| MN | 20.0 until Aug. 2007 15.0, Sept. 2007-Aug. 2010 10.0, Sept. 2010-Aug. 2013 (also, 1.5 cents/litre excise tax reduction for gasoline blended with 10% MN-made ethanol) | Ethanol must be produced and consumed in MN | No duration specified |
| Federal | 10.0 | No restriction on ethanol source | No duration specified |

Source: Klein et al, 2004

Table 1.5 Renewable fuel mandates for ethanol

| Jurisdiction | Consumption requirement | Implied consumption per year in 2012 (million litres) |
|---|---|---|
| **Federal** | 5% from 2010 | 2,145 |
| **Alberta** | 5% from 2010 | 290 |
| **British Columbia** | 5% from 2010 | 250 |
| **Manitoba** | 5% from January 2008; 8.5% from April 2008 | 135 |
| **Ontario** | 5% from January 2007 | 830 |
| **Quebec** | 5% from 2012 (cellulosic ethanol) | 445 |
| **Saskatchewan** | 1% from 2006; 7.5% from October 2006 | 125 |

Source: Laan et al, 2009

**FIGURES**

Figure 1.1 Net energy value of ethanol as a percentage of its fuel energy, showing results of many studies
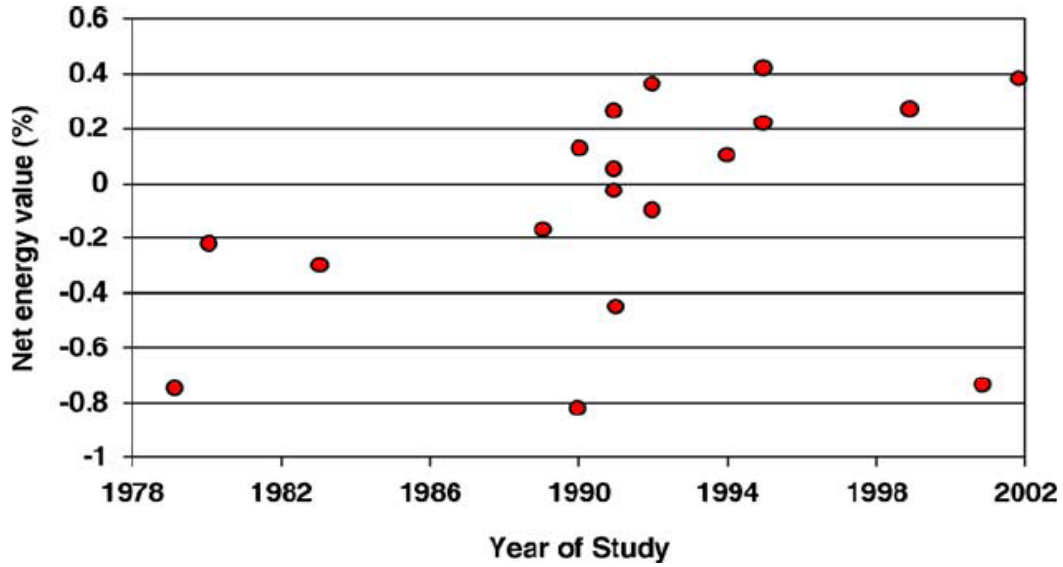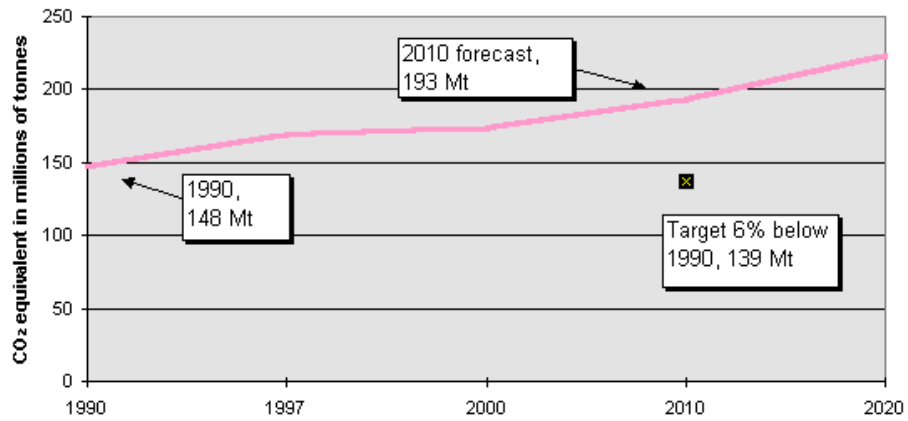


Source: Niven, 2005

Figure 1.2 Canada's GHG emissions



Source: Transport Canada (1999)

Figure 1.3 The gap between Canada's greenhouse gas emissions and its Kyoto target is growing
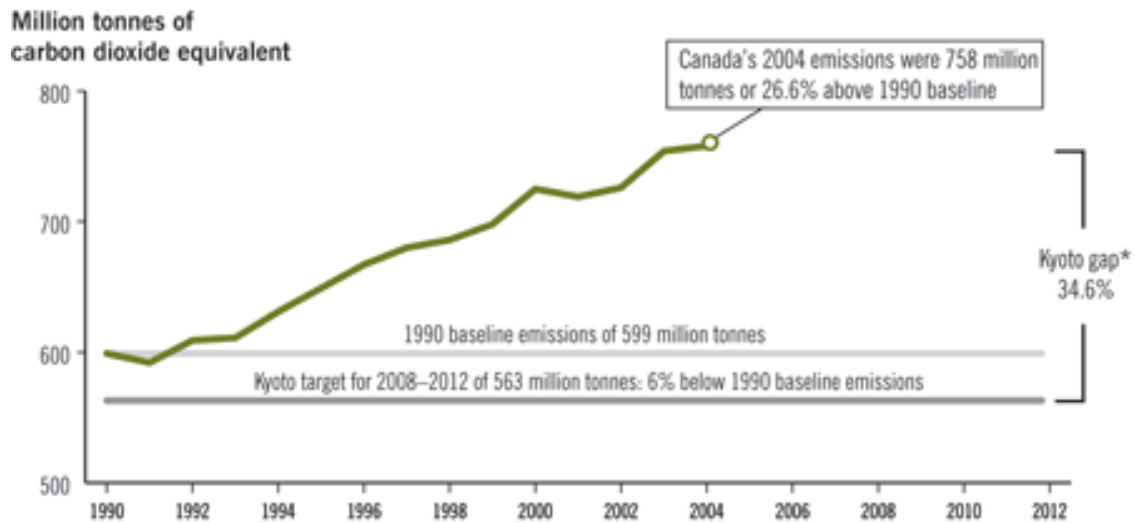


Source: Office of the Auditor General of Canada (2006)

Figure 1.4 Mapping an Investment Opportunity onto a Call Option

| Investment Opportunity | Variable | Call Option |
|---|---|---|
| Present value of a project's operating assets to be acquired | $S$ | Stock price |
| Expenditure required to acquire the project assets | $X$ | Exercise price |
| Length of time the decision may be deferred | $t$ | Time to expiration |
| Time value of money | $r_f$ | Risk-free rate of return |
| Riskiness of the project assets | $\sigma^2$ | Variance of returns on stock |

Source: Luehrman, T.A. (1998)

Figure 1.5 Subsidies and Countervailing Measures

Industrial Products

| **Prohibited:** | **Non-actionable:** | **Actionable:** |
|---|---|---|
| ⁻Export subsidies (not the case); | non-trade distorting subsidies. | trade distorting subsidies. |
| ⁻Subsidies contingent upon use of domestic inputs over imported inputs. | some environmental subsidies – but not the way they are paid for in biofuels | Ways of addressing: <br> ⁻Dispute settlement body of WTO; <br> ⁻Domestic investigation and countervailing duties. |

Source: authors

Figure 1.6 WTO Agreement on Agriculture

Domestic support

| **Amber Box** (actionable subsidies): | **Blue Box:** Amber box subsidies that satisfy specific conditions: | **Green Box** (non-actionable subsidies): |
|---|---|---|
| ⁻Support prices; | ⁻Production limiting programs. | ⁻Non or minimally trade distorting subsidies: |
| ⁻Subsidies directly related to production quantities. | At present – no limits. | ⁻Decoupled payments; |
| Reductions expressed in "Total Aggregate Measurement of Support": product specific and non-product specific supports in one single figure. | | ⁻Environmental programs; <br> ⁻Research and Development; <br> ⁻Food aid etc. <br> At present – no limits and no action can be taken against them. |

Source: authors