IMPACTS OF BIOFUELS PRODUCTION ON FOOD PRODUCTION IN THE PRAIRIE REGION OF CANADA

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Introduction

Biofuels (bioethanol, biodiesel and biogas) are those molecules derived from biological sources (plant or animal products), and can be used to carry energy for the production of work (mechanical, electric or transport) (Nickel, 2006). The fuels are most commonly hydrocarbons, which have shared characteristic that on their consumption, they only release the carbon that the source plants took up from the atmosphere during their lifetime. Thus, they are one of the most important and controversial substitute fuels for the non-renewable (mainly fossil) fuels currently in use (Doucet, 2007). A study by Nickel (2006) argued that the amount of global biofuel production was only 4.8 billlion litres in 2000. It was tripled to about 16.0 billion litres in 2007, but still accounted for less than 3% of the global transportation fuel supply.

Objectives

The purpose of this project is to study the impacts from biofuel production on the food production in the prairie region of Canada, which includes the provinces of Manitoba, Alberta and Saskatchewan.

On the Canadian Prairies, canola is a main source for biodiesel production and wheat is the primary feedstock for bioethanol production. However, approximately 70% of the vegetable oil in Canada comes from canola and wheat is used for making flour. To raise biofuel production requires a movement of resources and land away from food crops - wheat, canola and feed grains (barley, oat and rye, mainly used as feedstock for animals), which would cause food to become scarcer and increase its price.

Theory and Methodology

1.0 Production possibility frontier

The production possibility frontier (PPF) is a graph (Figure 1) representing the alternative combination of two outputs (goods or services) that can be efficiently produced during a specified period of time with a fixed quantity of inputs. To increase the quantity of one good produced, production of the other good must be sacrificed (Lipsey, 2002).

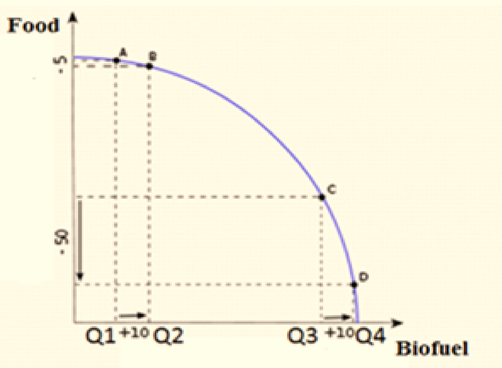

Figure 1: Production Possibility Frontier (PPF)
Source: Adapted from Barthwal (2007, p.31)

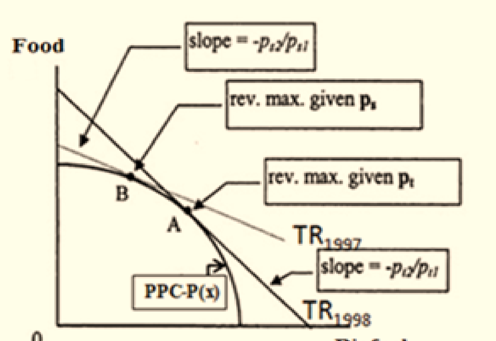

Figure 2: PPF and Revenue Function
Source: Coelli et al. (1998, p.46)

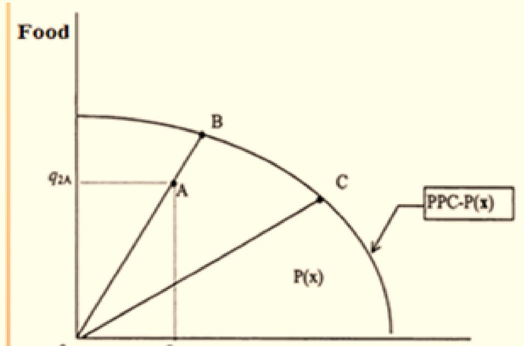

Figure 3: PPF and Output Distance Function
Source: Coelli et al. (1998, p.48)

2.0 Revenue Function and Distance Function

When revenue is maximized, the slope of revenue function equal to the slope of PPF. Consider a translog revenue function of *i* output prices (**p**$_i$, *i*=1,2,…,k) and one aggregate input quantity (x):

$$\ln R=\beta_0+\sum_{i=1}^{k+1}\beta_i \ln p_i^* +\frac{1}{2}\sum_{i=1}^{k+1}\sum_{j=1}^{k+1}\beta_{ij}\ln p_i^* \ln p_j^* \quad (1)$$

(Note: The ln*R* is the natural logarithm of the revenue function. The ln*pi* ∗ ={ln*p*$_1$,ln*p*$_2$,…,ln*p*$_k$,,ln*x*} is a vector of natural logarithms of output prices and input quantity. *p* is defined as a vector that includes {*p1,p2,…, pk*} and *β's* are parameters).

Given the existence of a production possibility frontier, the distance that any producer is away from the frontier is a function of the set of inputs used, **x**, and the levels of outputs produced, **y**. D_0 (x, y) is the distance from the firm's output set to the frontier. The translog distance function with *i (i=1,2,…,k)* outputs quantities (y_i) and one aggregate input (x) quantity can be represented by :

$$\ln D=\alpha_0+\sum_{i=1}^{k+1}\alpha_i \ln y_i^* +\frac{1}{2}\sum_{i=1}^{k+1}\sum_{j=1}^{k+1}\alpha_{ij}\ln y_i^* \ln y_j^* \quad (2)$$

(Note: ln*D* is the natural logarithm of the distance function, lny*i* ∗ = {lny$_1$,lny$_2$,…,lny$_k$, lnx} is either the natural logarithms of an output or input quantity and α's are parameters. y is defined as a vector that includes {y$_1$,y$_2$,…,y$_k$}, x is the aggregate input quantity).

This study considers the simultaneous estimation of share equations from both revenue function and distance function, using the assumption that all data are non-stationary (Clark et.al., 2013). The two functions are dual to one another, so the information contained in one function is identical to the other (Deaton, 1979). The parameters are estimated from the long-run structural modeling developed by Pesaran and Shin (2002), in which the correlations among shares between primal and dual models are exploited by cointegration techniques. The Johansen's maximum likelihood estimator is applied to 1971-2007 data from Manitoba, Alberta and Saskatchewan. Morishima elasticity estimates indicate high long run substitutions among crops (wheat, feed grains and canola).

From the Revenue function and Distance function, we can calculate the Elasticity (from eq.(3) and (4)) and Morishima Elasticity (from eq.(5) and (6)).

$$\varepsilon_{ji}(x,p)=\frac{p_i R_{ij}(x,p)}{R_j(x,p)} \quad (3)$$

$$\varepsilon_{ji}(x,y)=\frac{y_i D_{ij}(x,y)}{D_j(x,y)} \quad (4)$$

$$\sigma_{ij}^M(x,p)=\frac{p_i R_{ij}(x,p)}{R_j(x,p)}-\frac{p_i R_{ii}(x,p)}{R_i(x,p)}=\varepsilon_{ji}(x,p)-\varepsilon_{ii}(x,p) \quad (5)$$

$$\sigma_{ij}^M(x,y)=\frac{y_i D_{ij}(x,y)}{D_j(x,y)}-\frac{y_i D_{ii}(x,y)}{D_i(x,y)}=\varepsilon_{ji}(x,y)-\varepsilon_{ii}(x,y) \quad (6)$$

(Mundra and Russell, 2004)

Results

Table 1:Own-elasticity for Each Crop from Dual Functions

	Revenue Function			Distance Function		
	Wheat	Feed Grain	Canola	Wheat	Feed Grain	Canola
Manitoba	0.98	3.24	1.54	1.28	1.86	4.47
Alberta	1.08	1.88	1.17	3.26	2.00	1.27
Saskatchewan	4.73	2.54	4.26	1.42	1.97	1.98

From all long run own-elasticities in Table1, the increase of *i*th price will lead to the increase of the supplied quantity of output *i*, thus, the law of supply is satisfied. From the revenue function, the own-price elasticity of feed grains for three provinces are all elastic, especially for Manitoba as it has the highest elasticity value. Also, Saskatchewan has higher own-price elasticities for wheat (bioethanol) and canola (biodiesel) than the other two provinces, which indicates that Saskatchewan has the most potential for producing biodiesel and bioethanol within the three provinces.

Table 2:Morishima Elasticity of Substitution Matrix from Dual Functions

	Revenue Function			**Distance Function**		
	Manitoba			Manitoba		
	Wheat	Feed Grain	Canola	Wheat	Feed Grain	Canola
Wheat	0.00	-2.18	-1.06	0.00	-2.17	-1.55
Feed Grain	-5.26	0.00	-3.50	-3.37	0.00	-2.08
Canola	-1.81	-2.07	0.00	-5.37	-4.91	0.00
	Alberta			Alberta		
	Wheat	Feed Grain	Canola	Wheat	Feed Grain	Canola
Wheat	0.00	-2.21	-1.01	0.00	-4.29	-3.17
Feed Grain	-2.96	0.00	-2.46	-2.99	0.00	-2.64
Canola	-1.04	-2.38	0.00	-1.10	-2.58	0.00
	Saskatchewan			Saskatchewan		
	Wheat	Feed Grain	Canola	Wheat	Feed Grain	Canola
Wheat	0.00	**-5.83**	**-5.18**	0.00	-2.27	-1.81
Feed Grain	**-4.61**	0.00	**-2.14**	-3.59	0.00	-1.84
Canola	**-5.64**	**-3.62**	0.00	-3.20	-1.76	0.00

The Morishima elasticities are presented in Table 2. All diagonal elements are negative, indicating all outputs are net substitutes. All of the Morishima cross-elasticities for price-substitutes from revenue function are larger than one in the absolute value, and the biggest is wheat for feed grains in Saskatchewan.

Crops in Western Canada are highly substitutable.in the long run.

Government policies implemented to encourage either biodiesel or ethanol production will only have minimal impacts on other crop prices.

Conclusions

All estimated elasticities and Morishima elasticities of substitution from the revenue function and the distance function show that all outputs are net price-substitutes and net quantity-substitutes for Canadian Prairies. The negative and large Morishima elasticity estimates indicate that all substitutions among biofuel crops (wheat and canola) and food crop (feed grain) are elastic, and there are long run substitutions within the biofuel crops and also between the biofuel crops and food crop.

The Prairie region has a potential to produce both food and fuel over the long run.

These results assume that climate change will not greatly affect agricultural production in the region.

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