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PART ONE: Production Agriculture

3. The Impact of Technological Innovation on Producer Returns: The Case of Genetically Modified Canola

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Chapter 3

The Impact of Technological Innovation on Producer Returns: The Case of Genetically Modified Canola

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Introduction

Due to the relative ease with which it can be manipulated, canola was one of the first genetically modified (GM) crops to reach the commercial market in Canada. In 1998, after four years of production, herbicide resistant (HR) canola comprised 44 percent of total canola production in Canada (see Table 1). One source estimates that Canadian HR canola production could reach as high as 70 percent in 1999 (Plant Biotechnology Institute 1998).

TABLE 1 Acres of Herbicide-Resistant Canola, Canada (000 acres)

	1996	1997	1998	1999 (projected)
Total Canola	8,843	12,040	13,535	13,941
Herbicide Resistant	350	4,000	6,000	9,600
Percent of Total	4	33	44	69

Sources: AAFC, Canola Council of Canada, PBI, authors' calculations.

Although producers have been quick to adopt GM canola, questions arise as to whether the large R&D effort required to produce GM canola has provided benefits. These questions arise for at a number of reasons. First, the privately-funded nature of the R&D means the companies undertaking the R&D have only their own interests in mind when making R&D decisions. In this context, do any benefits spill over and accrue to other segments of the industry? Second, the firms conducting the R&D are all large, multinational enterprises and are operating in an industry that is increasingly concentrated. This increasing concentration suggests the firms may have the power to appropriate the benefits of the research largely for themselves.

Third, although producers have readily accepted GM canola for its agronomic benefits, consumers have raised concerns over the safety of GM products. While the North American market does not segregate GM and non-GM varieties of canola, several of Canada's export markets – most notably the EU – have refused Canadian canola due to consumer concerns over the safety of GM organisms (Western Producer 1999).

While there are a wide array of issues surrounding HR canola, the key question – Does it provide benefits to the farmer and to the rest of the supply chain? – should nevertheless be easy to answer. From a strictly economic perspective the answer appears to be quite simple: If the cost of growing HR canola – where this cost includes the cost of the seed, technology use agreements and chemicals – has fallen compared to the cost of growing traditional canola, then producers benefit. In turn, if producers benefit, then canola supply increases, which results in benefits to other sectors of the supply chain.

The purpose of this paper is to show that a determination of the producer benefits of HR canola is more difficult to obtain than is outlined above. The argument that producers benefit if the relative price of growing HR canola falls depends critically on the belief that all farmers are identical in the agronomic factors they face, the management skills they possess, and the other technology they have adopted. If farmers are different in these characteristics, no such easy test of producer benefit is available. Likewise, on the consumer side, the effect of a new technology like HR canola can only be understood if consumers are differentiated in their willingness to pay for traditional versus HR canola.

The next section of the paper examines a conceptual model in which producers are assumed to be identical. Under this assumption, producers typically benefit only when a new technology is drastic and completely takes over the market. The paper then examines the current pricing and adoption of HR canola in Canada. The conclusion reached is that attempts to understand the adoption of HR canola are problematic if it is assumed that producers are homogenous. The paper then argues that the appropriate conceptual model is not one where the technology can be thought of as being drastic or non-drastic, but rather one where both types of technologies can co-exist. The paper then develops a simple model in which producers – and then consumers – are differentiated and uses this model to draw some conclusions about the factors that affect the distribution of benefits to the players within the supply chain.

Producer Benefits of Agricultural R&D When Producers Are Identical

As Moschini and Lapan note, agricultural R&D has traditionally been carried out by public agencies. Agricultural R&D is increasingly being funded and carried out by private agricultural firms, particularly those in the seed and chemical input sector. This shift in the source of R&D activity has occurred in part because the growth in public expenditures has declined and in part because intellectual property rights (IPRs) have been introduced which have created incentives for private firms to undertake R&D (Moschini and Lapan 1997).

There is a substantial literature on how the benefits of agricultural R&D are distributed throughout the agricultural system when the R&D is publicly funded (see Alston, et al. (1995)

for an overview of this literature). The basic idea in this literature is that R&D creates cost savings or productivity increases that shift out one or more of the supply curves in the marketing chain. The sector most often examined as the location of the supply shift is the farm sector, although other sectors have been examined. Given this starting point, the analysis then examines the effect of these shifts on the various marketing sectors.

When R&D is privately funded the framework of analysis requires modification. As Moschini and Lapan note, the generation of cost savings or productivity increases as a result of privately-funded R&D does not necessarily shift outwards one or more of the supply curves. Instead, the firms undertaking the R&D may completely capture the benefits. The degree to which the benefits will be captured by the R&D firms depends critically on the market concentration of the R&D industry. The R&D industry is expected to be concentrated because the creation of a non-competitive market structure is generally understood to be one of the consequences of intellectual property rights (IPRs) (see Fulton (1997), Moschini and Lapan (1997), and Lesser (1998) for the arguments on this point). Intellectual property rights are provided to the companies to provide an incentive to undertake R&D.

Moschini and Lapan show that privately funded R&D provides benefits if the innovation resulting from the R&D is drastic. An innovation is defined as drastic if it is priced lower than the existing technology, thus completely taking over the market. An innovation is non-drastic if it is priced competitively with the existing technology. The notions of drastic and non-drastic innovation provide a relatively easy method of determining the distribution of benefits. Drastic innovations clearly provide benefits to the agricultural production sector and the rest of the supply chain. If the existing technology was being provided competitively, then the introduction of a new technology that is non-drastic will provide no benefit to the agricultural production sector, nor to other down-stream sectors. If the existing technology was not being provided competitively, non-drastic innovations can provide benefits to producers. Of course, both drastic and non-drastic innovations provide benefits to the firm that undertook the R&D (Moschini and Lapan 1997).

All things equal, the more concentrated is the seed and chemical industry, the more likely are seed and chemical prices to be raised to the point where an innovation becomes non-drastic. Concentration in the seed and chemical industry is a growing concern given the large number of mergers and acquisitions that have taken place recently (Hayenga 1998).

The notion of a drastic innovation is only relevant if all producers of the product face the same costs and agronomic factors. If production factors differ across farmers, however, then both the old and the new technologies can co-exist with some farmers benefiting from the technology and others not. The share obtained by each technology will depend on a host of factors, including the distribution of the farm-level cost savings of the new technology and the industrial structure of the seed industry.

The same conclusion holds on the consumer side. If consumers differ in their willingness to consume GM products versus non-GM products, then both the old and the new technologies can co-exist with some consumers benefiting from the technology and others not.

The next section of the paper provides some empirical evidence that the adoption of HR canola by farmers is best understood if the assumption that farmers are identical is relaxed and replaced with the assumption that they differ in terms of such characteristics as management ability, geographical location, and age.

Pricing and Adoption of Canola in Saskatchewan, Canada

Since its inception in 1996, the share of HR canola has risen from four percent to 44 percent of the total canola market in Canada (Table 1). Possessing the usual canola characteristics of short growing seasons, high yields and climate tolerance, the HR varieties also portray resistance to certain chemicals, which potentially provide further agronomic and cost benefits to the producer. The ability to apply a non-selective herbicide to the established crop effectively limits weed control to a one-pass operation. Production of non-HR canola typically requires two chemical applications, one pre-emergent and one post-emergent, where the post-emergent application only controls a limited spectrum of weeds. The one-pass chemical operation not only improves the yield potential of the crop by removing competition for moisture and nutrients, but also eliminates the cost of additional machine operations over the field.

HR canola is also becoming more appealing as farmers turn to conservation systems of land management. Conservation systems are being used to maintain higher levels of soil organic matter and to minimize soil erosion. Since tillage is minimized in these systems, weed control must be carried out solely with chemicals rather than with a combination of chemicals and cultivation, the usual method under traditional land management systems. The availability of a canola resistant to a chemical that can control the entire spectrum of weeds gives farmers much more flexibility in terms of the timing and type of weed control in conservation systems.

Table 2 compares the costs in 1999 of the commercially available HR systems with the traditional canola option, as estimated by Pioneer Grain Company. The cost of the conventional canola package is roughly equal to that of the HR systems and is somewhat higher than that of the Roundup Ready system. This pricing structure is similar to that found for 1996 by Mayer, who found the cost of the Roundup Ready system was \$43.58 per acre, compared to \$49.50 per acre for traditional canola (Mayer 1997). However, as Table 2 shows, the higher expected yield for conventional canola results in this system having the higher per acre returns. In spite of lower benefits to HR canola, the proportion of total Canadian canola acreage consisting of HR canola has been rising rapidly (Table 1). Although there is still a significant area of production in traditional canola, the HR system appears to be dominating.

TABLE 2 1999 Canola Product Line, System Comparison

	Roundup Ready	Smart Open Pol.	Liberty Hybrid	Conventional Open Pol
System Costs				
Seed Cost ($/acre)[a]	$18.70	18.70	24.75[b]	$13.47
Herbicide Cost ($/acre)	$5.00	$26.20	$22.75	$30.00
TUA ($/acre)	$15.00	None	None	None
System Cost ($/acre)	$38.70	$44.90	$47.50	$43.47
Gross Returns				
Yield (bu/acre)	33.0	31.5	35.7	35.7
Commodity Price ($/bu)	$8.00	$8.00	$8.00	$8.00
Expected Gross ($/acre)	$264.00	$252.00	$285.60	$285.60
Less System Costs ($/acre)	$(38.70)	$(38.25)	$(47.50)	$(43.47)
Gross Returns ($/acre)	$225.30	$213.75	$238.10	$242.13

[a] Seed cost was calculated assuming a seeding rate of 5.5 lbs./acre.
[b] Recommended seeding rate is 5 lbs./acre for Liberty Hybrids.
Source: Pioneer Grain Company Limited

The pricing and acreage data appear to be contradictory if all farmers are assumed to face the same production conditions and hence have the same costs and benefits. The data, however, are not contradictory if it is recognised that producers differ in certain respects. Indeed, farmer diversity is a hallmark of modern agriculture. Farmers differ substantially in terms of age, education, farm size, product specialisation, farm management skills, the geographical location of their farming operation, and the degree to which they have adopted conservation tillage methods. The next section of the paper develops a conceptual model in which producers are differentiated in some respect. The paper then examines the implications of differentiating consumers.

A Model of Differentiated Producers

Assume farmers are differentiated along some attribute, *A*, whether it is management ability, agronomic factors, or geographic location. For the canola producer producing traditional canola, per unit profits are:

(1) $$\pi_t = p^c - p_t^s + \gamma A$$

while the per unit profits of the canola producer producing GM canola are:

(2) $\boldsymbol{p}_{gm} = p^c - p^s_{gm} + \boldsymbol{f}A$

The per unit price of canola produced at the farm level is p^c; since GM and non-GM canola is not differentiated, there is only one price. The per unit prices of traditional and GM seed are p^s_t and p^s_{gm}, respectively, with the price of seed including the cost of the actual seed, plus associated chemicals. The term A shows the returns earned by farmers with different levels of the distinguishing attribute *A* when conventional canola is being produced. The term A shows the returns earned by farmers with different levels of the distinguishing attribute *A* when HR canola is being produced.

Figure 1 illustrates the basic concepts. The horizontal axis shows the attribute *A* that distinguishes farmers. Producers located at the extreme left-hand side of the diagram receive a net return on their traditional canola production equal to $p^c - p^s_t$. Producers with a larger value of *A* – for instance, farmers that have adopted some form of reduced tillage system – see higher returns. In the model these higher returns are linearly related to the level of the attribute that distinguishes farmers (in a more general model, these costs need not be a linear function of the attribute). Mathematically, the net return on traditional canola production is equal to $p^c - p^s_t + gA$, where is the additional benefit associated with a unit change in the differentiating attribute.

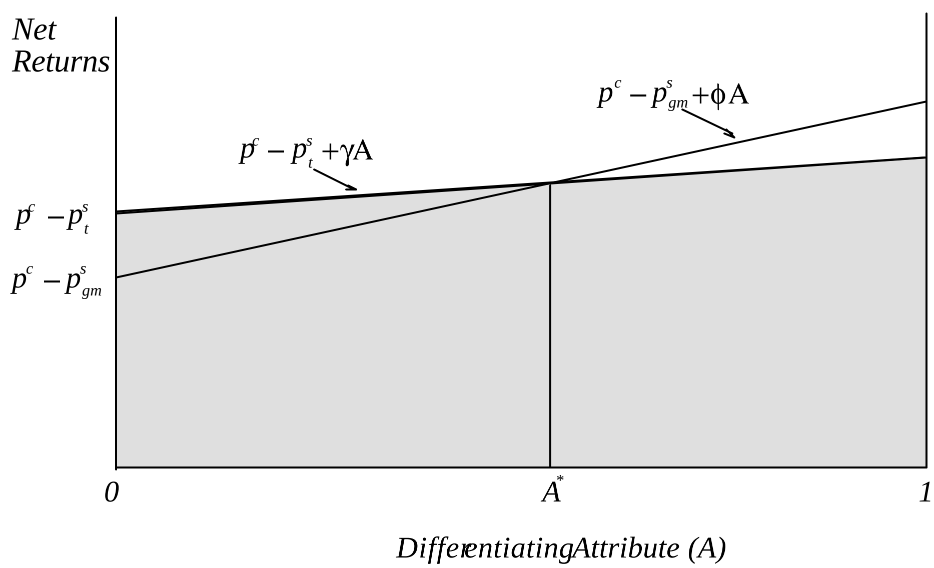

FIGURE 1 The Benefits of a New Technology With Differentiated Producers

Given this cost and benefit structure, the shaded area in Figure 1 gives the returns to traditional canola technology. Because farmers are differentiated according to some attribute, the benefit derived from the traditional technology is not the same for all farmers. Specifically, farmers with a higher A receive a greater benefit than do those with a lower A.

Now consider the introduction of a new technology such as GM canola. The cost of this technology is p^s_{gm}, where p^s_{gm} includes the cost of seed, plus associated chemicals and technology agreements. Producers located at the extreme left-hand side receive a net return on their HR canola production equal to $p^c - p^s_{gm}$. Producers with a higher value of A see higher returns. Mathematically, the net return on HR canola production is equal to $p^c - p^s_{gm} + fA$, where is the additional benefit associated with a unit change in the differentiating attribute.

As Figure 1 illustrates, producers located to the left of A^* find it profitable to remain with the traditional seed, since the returns to it are greater than the returns to the new seed. Producers located to the right of A^*, however, find it profitable to adopt the new seed. The clear area in Figure 1 is a measure of the benefits derived from the introduction of the new technology, namely HR canola. Notice that the farmers that benefit most from the technology are those that have a high value of A. Those farmers with an attribute value that is close to A^* obtain only a small benefit from the new technology.

Mathematically, the value of A^* can be determined by solving the following equation:

(3) $$p^c - p^s_{gm} + fA = p^c - p^s_t + gA$$

Thus:

(4) $$A^* = \frac{p^s_{gm} - p^s_t}{m} \qquad \text{where } m = f - g .$$

Assuming A is distributed uniformly between zero and one, the fraction of farmers producing GM canola is:

(5) $$q^c_{gm} = 1 - \frac{p^s_{gm} - p^s_t}{m}$$

Assuming the total amount of canola production is x^c, the quantity produced of GM canola is:

(6) $$x^c_{gm} = x^c q^c_{gm} = x^c - b\left(p^s_{gm} - p^s_t\right)$$

where $b = \frac{x^c}{m}$. Assuming a fixed proportions relationship between the quantity of seed required and the quantity of canola produced, the demand for GM seed is thus

$x_{gm}^{s} = x^{c} - b\left(p_{gm}^{s} - p_{t}^{s}\right)$. The inverse demand curve can be written as $p_{gm}^{s} = m + p_{t}^{s} - \frac{1}{b} x_{gm}^{s}$. The inverse demand curve is illustrated in Figure 2 as curve D_{gm}^{s}.

Assuming traditional seed is supplied competitively at price p_{t}^{s} (the presence of a public research effort is one reason why traditional seed may be supplied competitively), the question arises as to the price charged for GM seed. Given the demand for GM seed, the GM seed price that maximizes the profits of monopoly chemical and seed company can be determined. The problem facing the chemical and seed company can be written as:

(7) $$\max_{p_{gm}^{s}} \Pi = x_{gm}^{s}\left(p_{gm}^{s} - m_{gm}^{s}\right) - F$$

where m_{gm}^{s} is the marginal cost of producing the GM seed and F is the fixed cost. The price of traditional canola is assumed to be constant.

The first-order condition for this problem is:

(8) $$\frac{\partial \Pi}{\partial p_{gm}^{s}} = x_{gm}^{s} + \left(p_{gm}^{s} - m_{gm}^{s}\right)\frac{\partial x_{gm}^{s}}{\partial p_{gm}^{s}} = 0$$

where $\frac{\partial x_{gm}^{s}}{\partial p_{gm}^{s}} = -\frac{1}{b}$.

Solving for the optimal GM seed price gives:

(9) $$p_{gm}^{s} = \frac{1}{2}\left(m + p_{t}^{s} + m_{gm}^{s}\right) = 0$$

Using this expression for the price of GM seed, the price differential between GM canola and traditional canola is:

(10) $$p_{gm}^{s} - p_{t}^{s} = \frac{1}{2}\left[m - p_{t}^{s} + m_{gm}^{s})\right]$$

The derivation of the optimal GM seed price is shown graphically in Figure 2. For a profit-maximizing seed and chemical company, the demand curve is D_{gm}^{s}, while the marginal cost is m_{gm}^{s}. The optimal GM seed price is determined by setting MR (the marginal revenue curve to demand curve D_{gm}^{s}) equal to marginal cost (m_{gm}^{s}). Since the intercept of the demand curve depends on the price of traditional canola seed, changes in the price of traditional canola will influence the optimal GM seed price. Also, the model can easily be extended to allow for oligopolistic pricing rather than monopolistic pricing of GM seed (see below).

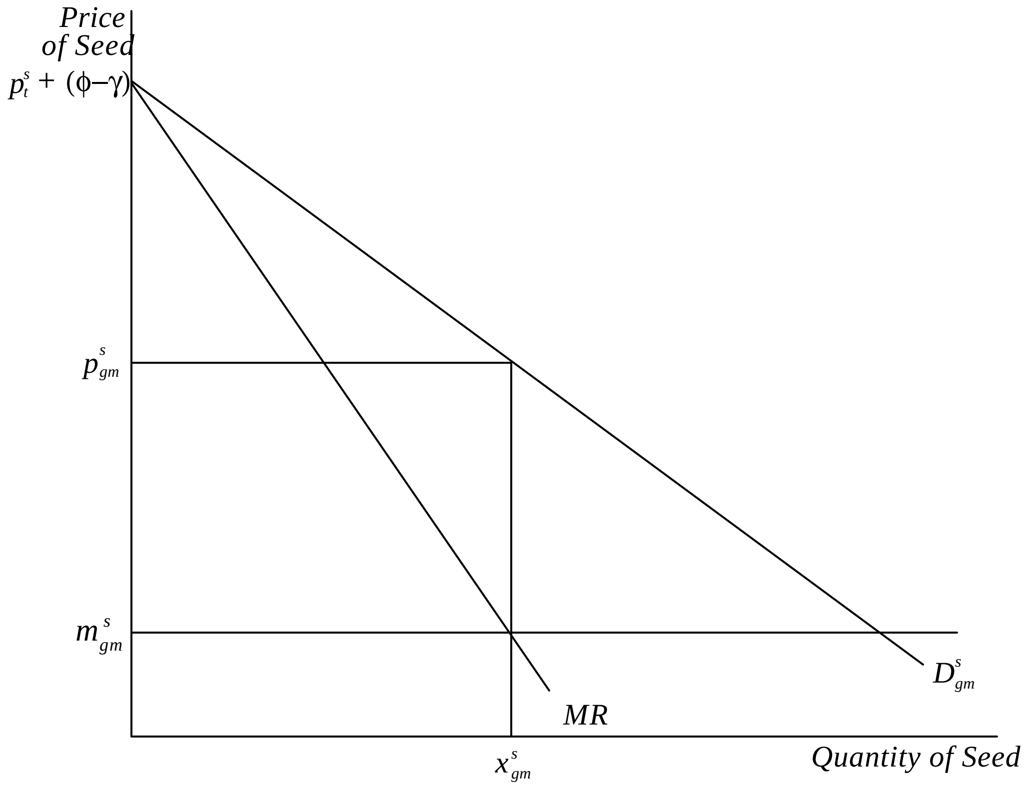

FIGURE 2 Determination of the Optimal GM Seed Price

The total benefit to farmers from canola seed technology is given by the sum of the benefits from traditional canola and the benefits obtained from adopting GM canola. The benefits of traditional canola are given by the shaded area in Figure 1 and can be written mathematically as:

(11) $$\Pi_t = p^c - p_t^s + \frac{g}{2}$$

where Π_t are the aggregate benefits to farmers when no GM existed. The benefits that result from adoption of GM canola are given by the clear area in Figure 1. Mathematically, this area is given by:

(12) $$\Delta\Pi = \frac{1}{2}[1 - A^*][(p^c - p_{gm}^s + f) - (p^c - p_t^s + g)]$$

Solving this expression gives:

$$(13) \qquad \Delta\Pi = \frac{1}{2m}[m - (p_{gm}^{s} - p_{t}^{s})]^{2}$$

Substituting in the expression for the price differential results in:

$$(14) \qquad \Delta\Pi = \frac{1}{8m}[m + p_{t}^{s} - m_{gm}^{s}]^{2}$$

Thus, the total benefits of the seed technology are given by:

$$(15) \qquad \Pi = \Pi_{t} + \Delta\Pi = p^{c} - p_{t}^{s} + \frac{g}{2} + \frac{1}{8m}[m + p_{t}^{s} - m_{gm}^{s}]^{2}.$$

The model allows a number of conclusions to be reached. First, the model shows that some producers benefit even if only a portion of the market switches to the new technology – i.e., the technology does not have to be drastic for there to be a producer benefit. Moreover, the model shows that producers can benefit and a portion of producers will adopt the new technology, even when the new technology appears to be priced higher than the old technology (compare $p^{c} - p_{t}^{s}$ to $p^{c} - p_{gm}^{s}$ at the left-hand side of Figure 1). Thus, the data presented in presented in Table 1 and Table 2 are not inconsistent with each other – HR canola can be priced such that the basic returns to conventional canola are higher and it can still be adopted by a significant portion of farmers.

Second, the price of traditional seed is a key factor in determining the benefits of the traditional seed and the benefits of the new technology. Specifically, all else equal, decreases in the price of traditional seed result in an increase in the benefits of traditional canola, a fall in the share of farmers that use HR canola, and a fall in the benefits of adopting HR canola. This result can be seen graphically shifting upward the $p^{c} - p_{t}^{s} + gA$ line.

The third observation to be made is that the price of HR seed is an important factor determining the benefits of the new technology. Graphically, an increase in p_{gm}^{s} leads to a downward shift in the $p^{c} - p_{gm}^{s} + fA$ line. This downward shift results in a smaller portion of farmers adopting the new technology and a smaller clear area.

An important factor influencing the price of HR seed is the market structure of the seed and chemical industry. As discussed earlier, the market structure of this industry is unlikely to be one of perfect competition because of the presence of IPRs. Figure 2 illustrates how a monopoly firm in the seed and chemical industry determines the price of HR seed. The model can be easily extended to allow for oligopolistic pricing rather than monopolistic pricing of HR seed. If the industry is not a monopoly, the HR seed price is determined by equating a modified marginal revenue curve with the marginal cost curve (Alston et al. 1997). The modified marginal revenue curve is constructed by rotating the marginal revenue curve towards the demand curve. The degree to which the curve is rotated reflects the degree of market competition. For instance, if competition among the seed and chemical companies is low, the rotation of the modified marginal revenue curve is small and the price of HR seed is close to the monopoly price. If competition is high, the price of HR seed is close to the price under perfect competition (in the case of perfect competition, the modified marginal revenue curve would lie on top of the demand curve). As noted above, the price of HR seed is one of the factors determining the benefits obtained from HR canola.

As noted above, the price of traditional seed affects the price of HR seed. As the price of traditional seed falls, the price of HR seed also falls. One implication of this result is that breeding programs that are directed at lowering the cost of traditional canola seed (such as those carried out in public institutions) are likely to be important in ensuring that HR canola is priced so that benefits accrue to farmers.

A Model of Differentiated Producers and Consumers

The rise of consumer concerns over GM products suggests consumers differ in their willingness to pay for GM versus non-GM food products. In this section we develop a model of canola seed pricing where traditional and GM canola are segregated and marketed separately. The development of this model requires a conceptual framework in which both consumers and producers are differentiated.

Consider a consumer of canola oil with the following utility functions:

$$(16) \quad \begin{aligned} U_t^o &= U - p_t^o && \text{if a unit of traditional oil is consumed} \\ U_{gm}^o &= U - p_{gm}^o - \lambda c && \text{if a unit of GM oil is consumed} \end{aligned}$$

where U_t^o is the per unit utility associated with purchasing traditional canola oil and U_{gm}^o is the per unit utility associated with purchasing GM canola oil. The price of oil made from traditional canola is p_t^o, while the price of oil made from GM canola is p_{gm}^o. The term c gives the discount in utility from consuming GM canola. The parameter is constant across all consumers, while the characteristic c differs according to consumer. Thus, consumers with large values of c will tend to prefer traditional canola rather than GM canola, all else equal.

The consumer with a value of c equal to c^* will be indifferent between consuming traditional oil or GM oil. The value c^* can be determined by solving the following equation:

$$(17) \quad U - p_t^o = U - p_{gm}^o - \lambda c^*$$

Thus:

$$(18) \qquad c^* = \frac{p_t^o - p_{gm}^o}{l}$$

Assuming c is distributed uniformly between zero and one, the fraction of people purchasing traditional canola oil is:

$$(19) \qquad q_t^o = 1 - \left(\frac{p_t^o - p_{gm}^o}{l} \right)$$

Assuming the total amount of canola oil consumption is x^o, the quantity consumed of traditional canola oil is

$$(20) \qquad x_t^o = x^o q_t^o = x^o - b(p_t^o - p_{gm}^o)$$

where $b = x^o /$.

Now consider the supply of canola at the farm level. Assume the profits of the canola producer producing traditional canola are:

$$(21) \qquad p_t = p_t^c - p_t^s + gA$$

while the profits of the canola producer producing GM canola are:

$$(22) \qquad p_{gm} = p_{gm}^c - p_{gm}^s + fA$$

The price of traditional canola produced at the farm level is p_t^c, while the price of GM canola produced at the farm level is p_{gm}^c. The price of traditional and GM seed is p_t^s and p_{gm}^s, respectively.

The producer with a value of A equal to A^* will be indifferent between producing traditional or GM canola. The parameter A^* is determined as follows:

$$(23) \qquad A^* = \frac{(p_t^c - p_t^s) - (p_{gm}^c - p_{gm}^s)}{m} \qquad \text{where } m = (f - g).$$

Assuming A is distributed uniformly between zero and one, the fraction of farmers producing traditional canola is:

$$(24) \qquad q_t^c = \frac{(p_t^c - p_t^s) - (p_{gm}^c - p_{gm}^s)}{m}$$

Assuming the total amount of canola oil production is x^c, the quantity produced of traditional canola is:

$$(25) \qquad x_t^c = x^c \boldsymbol{q}_t^c = \boldsymbol{b}\left[\left(p_t^c - p_t^s\right) - \left(p_{gm}^c - p_{gm}^s\right)\right]$$

where $\boldsymbol{b} = \dfrac{x^c}{m}$. This last equation can be rewritten as:

$$(26) \qquad x_t^c = \boldsymbol{b}\left[\left(p_t^c - p_{gm}^c\right) + \boldsymbol{d}^s\right]$$

where $\boldsymbol{d}^s = (p_{gm}^s - p_t^s)$ is the price differential between GM canola seed and traditional canola seed.

Assume canola is converted into canola oil through a fixed proportions production function that combines canola and processing services to produce canola oil. The implications of the fixed proportions production function is that $x^c = x^o$, $x_t^c = x_t^o$, and $x_{gm}^c = x_{gm}^o$. In addition, assuming perfect competition in the production of canola oil results in $p_t^o = p_t^c + p_t^p$ and $p_{gm}^o = p_{gm}^c + p_{gm}^p$, where p_t^p and p_{gm}^p are the prices of the processing services for traditional and GM canola, respectively.

Equating x_t^c and x_t^o and using the price equalities above results in:

$$(27) \qquad x^o - bp_t^c - bp_t^p + bp_{gm}^c + bp_{gm}^p = \boldsymbol{b}p_t^c - \boldsymbol{b}p_{gm}^c + \boldsymbol{d}^s$$

Solving for $p_t^c - p_{gm}^c$ gives:

$$(28) \qquad p_t^c - p_{gm}^c = \frac{x^o - b\boldsymbol{d}^p - \boldsymbol{bd}^s}{(b + \boldsymbol{b})}.$$

where $\boldsymbol{d}^p = p_t^p - p_{gm}^p$.

Substituting the expression for $p_t^c - p_{gm}^c$ into the equation for x_t^c results in the derived demand for traditional canola at the farm level:

$$(29) \qquad x_t^c = \frac{\boldsymbol{b}}{(b + \boldsymbol{b})}\left[x^o - b\boldsymbol{d}^p + b\boldsymbol{d}^s\right]$$

Assuming the quantity demanded of seed equals the quantity demanded of canola, the derived demand for GM seed can be obtained by noting that $x_{gm}^s = x_{gm}^c = x^o - x_t^c$. Thus:

$$x_{gm}^{s} = bx^{o} + \frac{b\boldsymbol{b}}{(b+\boldsymbol{b})}\boldsymbol{d}^{p} - \frac{b\boldsymbol{b}}{(b+\boldsymbol{b})}\boldsymbol{d}^{s} \tag{30}$$

Using the demand for GM seed, the optimal GM seed price that maximizes the profits of a chemical and seed company can be determined. The problem facing a chemical and seed company can be written as:

$$\max_{p_{gm}^{s}} \Pi = x_{gm}^{s}\left[p_{gm}^{s} - m_{gm}^{s}\right] \tag{31}$$

The first-order condition for this problem is:

$$\frac{\partial \Pi}{\partial p_{gm}^{s}} = x_{gm}^{s} + (p_{gm}^{s} - m_{gm}^{s})\frac{\partial x_{gm}^{s}}{\partial p_{gm}^{s}} = 0 \tag{32}$$

where $\dfrac{\partial x_{gm}^{s}}{\partial p_{gm}^{s}} = -\dfrac{b\boldsymbol{b}}{(b+\boldsymbol{b})}$

Solving for the optimal price for GM seed gives:

$$p_{gm}^{s} = \frac{1}{2}\left[\boldsymbol{l}(b+\boldsymbol{b}) + p_{t}^{s} + \boldsymbol{d}^{p} + m_{gm}^{s}\right]. \tag{33}$$

The model developed above allows a determination to be made of the impact of canola segregation on producers and consumers. As in the model developed in the previous section, the greater is the price of GM seed, the more those farmers that would otherwise benefit from growing GM canola will lose. Farmers that typically grow traditional canola because of its cost structure– i.e., farmers with low values of A – see no change in their welfare at all.

On the consumer side, the possibility exists that all consumers could lose. People who prefer traditional canola – i.e., consumers with large values of c – will lose because the price of this product rises when GM canola is introduced. The price of traditional canola rises because the cost of keeping this product segregating from GM canola is added to the price (in the model, the p_{t}^{p} is assumed to increase over what it would have been prior to the introduction of GM canola, thereby resulting in a higher price for canola oil).

People who are willing to purchase GM canola could also lose, largely because the price of GM canola is unlikely to fall below what traditional canola sold for prior to the introduction of GM canola. The reasoning is as follows. The price of GM canola seed does not have to fall below the price of traditional seed – indeed oligopolistic firms wishing to maximize profits prefer that it does not (see equation (33) which indicates that the price of GM seed can be above the price of traditional seed). With a higher seed price, the price of GM canola has to rise to make sure that GM canola is profitable to produce. The result is that the price of GM canola oil can actually be priced higher than what canola oil was prior to the introduction of GM canola. This outcome is even more likely if the cost of storing and handling GM canola rises as a result of segregation.

Concluding Remarks

The commercial sale of GM canola has raised the question of the benefits of this new technology to the seed and chemical companies, farmers, consumers, and other players in the supply chain. Previous research has suggested that the key characteristic determining whether technology of this type will provide benefits to groups other than the seed and chemical companies is whether the technology is drastic or non-drastic.

The characterization of innovations as being drastic or non-drastic hinges upon the assumption that neither producers nor consumers are differentiated in any fashion. If producers and consumers are differentiated, then a different conceptual framework is required to analyze the impact of innovations such as GM canola.

This paper argues that the pricing and adoption of GM canola in Canada cannot be understood if producers are seen as being homogeneous. The paper then develops a conceptual framework in which producers are differentiated. A key finding that emerges from this framework is that while some producers will not benefit from the new technology, others will, even when the new technology co-exists with the traditional technology. Thus, the idea that producers can benefit from the technology only if the technology is drastic is found to be limiting.

The paper also examines the impact of segregating GM and traditional canola in the marketing system. The segregation of canola only makes sense if consumers have a different willingness to pay for traditional canola versus GM canola. The main result of this part of the paper is that not all producers and consumers benefit from the introduction of segregation. While some producers are likely to benefit from the introduction of GM canola, the possibility exists that all of the consumers may be actually worse off.

Endnotes

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