Agrobiotechnology, seed industry and intra-crop diversity: the case of canola in Canada

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Abstract

With the diffusion of agro-biotechnology the canola seed industry in Canada has gone through profound changes. On one hand, through a process of both vertical and horizontal integration, the industry has become more concentrated. On the other, privatization of the R&D activities for the development of new varieties has occurred. These changes have in turn affected the set of canola varieties available to farmers and hence the canola production system. Specifically in Canada we have assisted to a proliferation of *Brassica napus* varieties to the expenses of *Brassica rapa* varieties. Today canola production in Canada is essentially a monoculture and interest in diversification is confined to public institutions. This might reflect a technological lock-in where the private industry is unwilling to invest in alternative species in order to diversify canola production. In the case of agricultural crops the degree of differentiation (i.e. intra-crop diversity) is a key element in determining productivity.

This paper, drawing on the Canadian experience, looks at how changes in the seed industry have affected the degree of diversity within the canola production system and tries to assess its impact on productivity.

Key words: horizontal and vertical integration, product differentiation, technological lock-in, within crop diversity, *Brassica napus*, *Brassica rapa*.

1 Introduction

From an economic perspective, one of the main consequences of the recent developments in agro-biotechnology has been the increasing concentration of the seed industry. Particular interest has been devoted to the issue of non-competitive practices adopted by the biotech multinationals (e.g. Qaim and De Janvry, 2003) and the effects of increasing concentration on technological innovation (e.g. Gray et al. 2000a). Concentration of the seed industry, however, is not the only institutional change associated with developments in agro-biotechnology. Another important aspect concerns the privatisation of R&D activities for the development of new crop varieties. Both factors (i.e. consolidation and privatisation) are likely to affect the number and the 'characteristics' of the crop varieties provided to farmers. Concentration in the seed industry could weaken the incentives to increase diversification and could lead to a technological lock-in (e.g. Arthur, 1994).

In this paper we draw on the Canadian experience with the canola crop (*B. rapa* and *B. napus*) in order to investigate the effects of the structural changes mentioned above on the diversity of the canola crop and (indirectly) on its productivity.

The structure of the paper is as follow. In section two we briefly look at the process of horizontal and vertical integration within the biotech and seed complex. In section three we look at the consequences on the canola production system in Canada. In section four we briefly address the issue of privatisation in R&D activities and its impact on canola varieties. In section five provide a preliminary assessment of the effect of canola varieties on productivity (mean and variance). In section six we draw some major conclusions.

2 Industry structure and product differentiation: a brief overview

In more recent years a wave of mergers and acquisitions has led to the consolidation of the major diversified biotechnology companies (e.g. Monsanto, Du Pont etc.) and to an increasing concentration of the seed industry around few multinational players.

The process of horizontal integration and industry consolidation is not unique to the agricultural biotechnology sector. However at least two characteristics of the agricultural biotechnology industry can help to explain the phenomenon (Fulton and Giannakas, 2001):

- *Sunk costs:* the existence of large sunk costs requires prices to be above the marginal costs. This is typically achieved by reducing the competition in the industry. The biotechnology industry requires large initial investments in R&D, marketing (endogenous sunk costs) and patent registration (exogenous sunk costs). The existence of sunk costs creates economies of scale and scope which tend to favour larger firms.
- *Escalation strategies:* these strategies are particularly profitable when scope economies exist on the supply side and product complimentarity (e.g. particular crop varieties and specific herbicides) exist on the demand side (Sutton, 1998).

The development of agricultural biotechnology has also been accompanied by a process of consolidation of the seed industry in the hands of few multinationals (i.e. vertical integration).

Transaction costs can help to explain the process of vertical integration. For the commercial introduction of GM crops, coordination of technological know-how, intellectual property rights and proprietary germplasm is required. Such coordination can be obtained either through contracts (e.g. joint ventures) or through vertical integration. The preference for vertical integration is mainly due to:

- *Weak appropriability:* the intellectual property rights for the technological know-how have been highly disputed. In this context the acquisition of germplasm (i.e. seed companies) turned out to be a better option;
- *Transaction costs:* contracts for the exploitation of agricultural biotechnology are necessarily incomplete (due to the complexity of the technology) and therefore transaction costs tend to be high;
- *Hold-up problems:* proprietary germplasm represents an essential complimentary asset to biotechnology know-how in order to deliver genetically modified crops. Given the large amount of resources invested in biotechnology R&D, 'hold-up' problems could easily emerge.

The impact of increasing concentration in the biotech and seed industry on the agricultural sector has not been fully assessed yet. The main concerns relate to the effect on consumer welfare, investment in new varieties and ultimately on crop diversity (e.g. number of different varieties grown). With respect to the first point Munro (2003) shows how a reduction in consumer welfare is not directly a consequence of concentration, but requires more stringent conditions (e.g., monopoly in the GM technology, high costs of germplasm conservation, pre-existing uniformity in the varieties being grown). With respect to the second point (investment on new varieties and reduction of crop diversity) further investigation is required. Arthur (1994) clearly illustrates how when a technology shows increasing returns to scale a lock-in can take place and potentially superior technologies can eventually be locked-out.

The study of the interactions between industry structure and product differentiation stems from the work of Chamberlin (1933) on monopolistic competition. The level of product differentiation in an industry is the result of the interaction among different forces. Spence (1976) maintains that when introducing a new product a firm has to balance the advantage of eroding competitors markets (inter-firm competition) with the disadvantage of eroding its own (existing) products market (intra-firm competition). Schmalensee (1978) and Scherer (1979) show how increasing concentration can induce product 'proliferation'.

Specifically they show that if the market is (not) contestable then a more concentrated industry will be characterised by more (fewer) varieties (Beath and Katsoulakos, 1991).

Other elements that influence the degree of product differentiation include the existence of economies of scale and scope. So, for example Lancaster (1979) shows that when economies of scale are present, the degree of product differentiation will decrease when the industry becomes increasingly concentrated. The same author (Lancaster, 1990) showed that the existence of economies of scope works in the opposite way by creating incentives towards greater differentiation.

3 Canola production in Canada

In this section we look at how the canola production system in Canada has changed over the past 15 years. Traditionally canola production included two different species, *B. napus* and *B. rapa*.

We begin our analysis by looking at the effects of industry concentration on canola varieties. We start by taking an index of product differentiation that reflects the number of commercial varieties of *B. napus*grown. Data on the acreage of different varieties grown in the three Prairies Provinces of Canada (Alberta, Manitoba and Saskatchewan) were extrapolated from the Prairies Pools Surveys (1972-1989) and the Prairies Grain Variety Surveys (1990-2003) data obtained through the Canadian Grain Commission. Using these data a Shannon index of diversity (H) was computed for the three provinces over the period 1990-2003.

$$H = -\sum_{i1}^{S} P_i \ln P_i \quad (1)$$

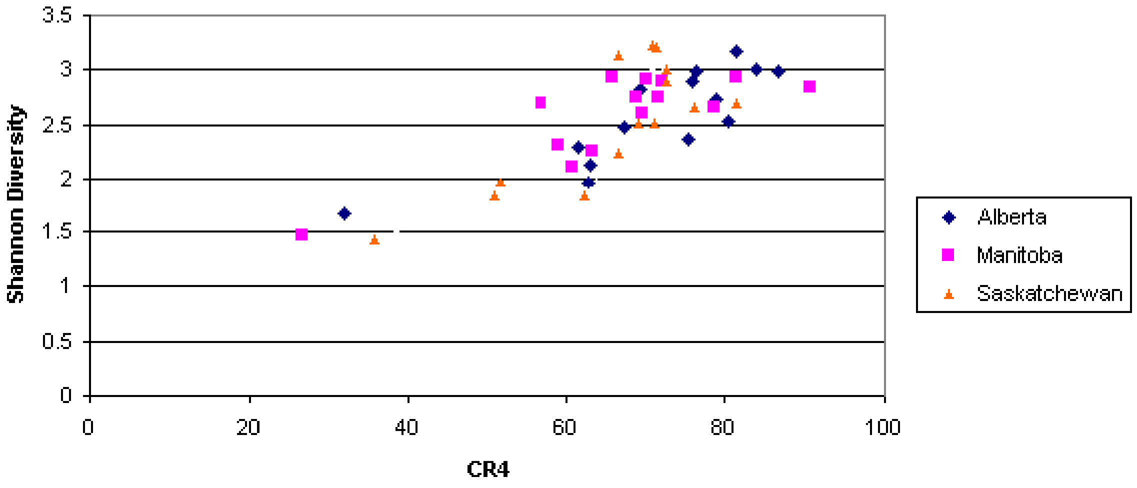
where

P_i: Proportion of total canola acreage planted with variety i; S: total number of varieties.

The diversity index associated with the number of different varieties of *B. napus* increased over the period 1990-2003 from around 1.5 to 3 for all three Provinces. *B. napus* varieties in Canada have passed from 17 to 82.

The concentration in the canola seed industry is measured through the four-firms concentration ratio (CR4). The CR4 indicates the market share of the 4 largest firms in an industry. Given the unavailability of detailed data on the seed sales values, the index has been computed by using variety acreage. As such the CR4 indicates the proportion of total *B. napus* acreage planted with varieties developed by the 4 largest private breeders.

Figure 1: Variety diversity of *B. napus* and seed industry concentration



Source: extrapolated from the Prairies Pools Surveys (1972-1989) and the Prairies Grain Variety Surveys (1990-2002)

Our data show that the CR4 for the three Prairies Provinces over the period 1990-2003 has passed from around 30% to around 80%. This reflects an increase in the importance of private breeders and an increase in concentration within the private breeding sector.

A simple scatter plot of the diversity index (H) against the CR4 illustrates a positive relationship between *B. napus* diversity and seed industry concentration (Figure 1).

Using the regression model

$$Log(H) = \beta_1 Log(CR4) + \beta_2 Log(Time) + u \quad (2)$$

where

H: Shannon diversity index for *B.napus* canola varieties; *CR4*: 4-firms concentration ratio

the relationship between industry concentration, technical innovation and diversity of *B. napus* variety is made clear (table 1).

Table 1: Concentration in the seed industry and variety diversity of *B. napus*

Variables	*Coefficient*
Log(CR4)	0.1224***
Log(Time)	0.2251***
Adj. R^2	0.8936

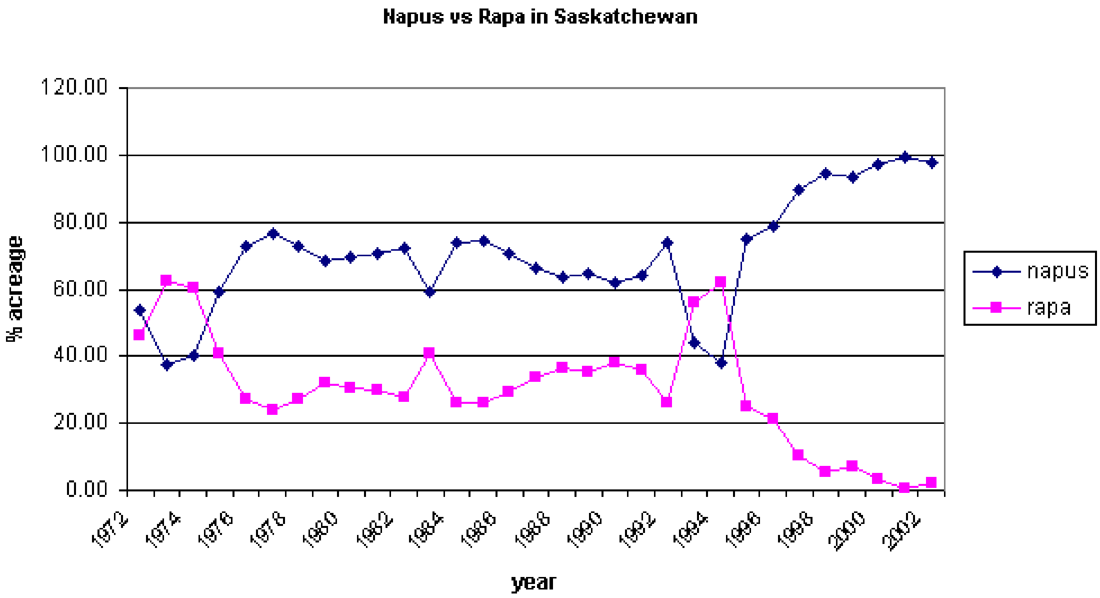
***Significant at 1% level

Before interpreting the result it is necessary to offer some historical perspective. In 1985 the Seed Act was modified. New varieties were now required only to be *'equivalent to'* and not *'better than'* the existing varieties. At the same time the 'committees' for assessing the varieties changed, and industry representatives played a greater role. Such amendments have made the introduction of new varieties much easier. From the economic point of view the interpretation of the results illustrated in Table 1 implies the existence of economies of scope (associated with large R&D expenditures). At the same time the proliferation of new varieties can be interpreted as an attempt by the dominating firms to block the entrance of new companies. The fact that most of the new varieties (called 'me-too' varieties) are very close substitutes supports this idea.

Following the increased concentration in the seed industry in the 90s, a large number of *B. napus* varieties flooded the market. Does this reflect a greater degree of differentiation?

Traditionally the canola crop in Canada has been constituted by two different species: *Brassica napus* (i.e. Argentine canola) and *Brassica rapa* (i.e. Polish canola). *B. rapa* is characterised by a shorter growing season, lower yield under optimal conditions but higher stability under non-optimal conditions (Rakow *et al*., 2003).

Figure 2: Displacement of *B.rapa* varieties by *B. napus* in Saskatchewan



Source: extrapolated from the Prairies Pools Surveys (1972-1989) and the Prairies Grain Variety Surveys (1990-2002)

After 1994, the acreage of *B. rapa* sharply declined (figure 2).The decline of *Brassica Rapa* is mainly due to:

- *Availability of chemical weed control:* herbicides have allowed for earlier sowing. As such *B. rapa* varieties with shorter growing seasons have become less important in weed control practices.
- *Hybrid technology:* the hybrid technology was mainly available for *B. napus* varieties.
- *Development of GM HT technology:* the availability of herbicide tolerant varieties has further improved weed control and reduced the need for cultivation and short growing season varieties.
- *Weediness of B. rapa:* the characteristics of this species (e.g. longer dormancy of the seeds) have resulted in a limited application of the HT technology.

The regression model

$$rapa = \beta_0 + \beta_1 (AugMinT) + \beta_2 (Time) + u \quad (3)$$

where

rapa: % of canola acreage sown with *B. rapa*; *AugMinT*: minimum Temperature in August in the previous year; *Time*: time index

helps us to understand the reasons behind the gradual disappearance of *B.rapa* varieties in the three Prairies Provinces of Canada over the period 1972-2002. The introduction of the variable (*AugMinT*) reflects the fact that when *B. napus* has been hit by the autumn frost in August, the acreage of *B. rapa* usually increases in the following year. The time index is used as a proxy variable for technological development (availability of herbicides, HT technology, hybrid technology).

Table 2: Analysis of the decline of *B. rapa* varieties

Variables	*GLS*	*FE*	*RE*
Constant	115.75***		109.58***
AugMinT	-2.83***	-1.49	-1.64*
Time	-3.39***	-3.31***	-3.33***
Adj. R^2	**0.50**	**0.62**	**0.52**
LM		4.59**	
Hausmann Test		1.46	

*Significant at 10% level; **Significant at the 5% level; ***Significant at the 1% level

The model has been corrected for heteroskedasticity (Generalised Least Squares). The LM and Hausmann Test suggest that the random effect model (RE) is the most appropriate. The results suggest that technical development (availability of herbicides, HT technology, hybrid technology) has been the main factor for the disappearance of the *B. rapa*. The climatic variable is not significant at the 5% level (p=0.0518).

In ecology it is well known that having similar plants that respond differently to weather randomness ensures that "whatever the environmental conditions there will be plants of a given type that thrives under these conditions" (Heal, 2000) and this allows the agroecosystem to maintain its productivity over a wider range of conditions.

It is then clear that proliferation of 'me-too' *B. napus* varieties did not increase the degree of diversity in the canola crop in Canada. At the same time the disappearance of some distinct canola species (i.e. *B. rapa*) reflects a reduction in the degree of diversity.

4 Privatisation of R&D activities

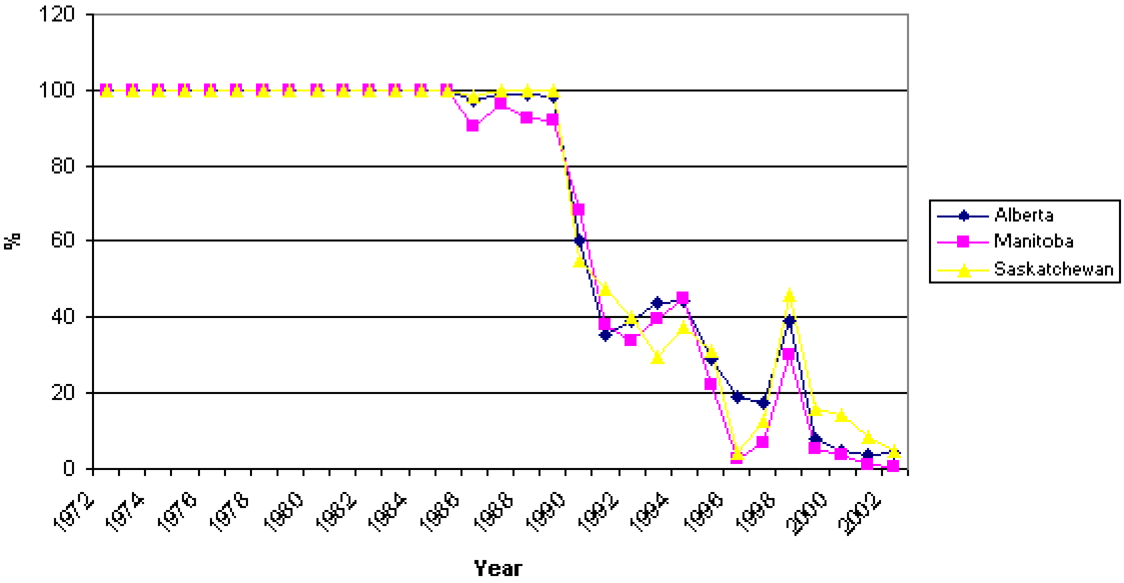
By 1994 it was clear that the market for *B. rapa* was declining. By the same time R&D activities for the development of canola varieties were almost entirely privately funded. This is in sharp contrast with the pre-1990 situation, when canola varieties were mainly the result of public funded research.

The diffusion of agricultural biotechnology has been accompanied by a strengthening of IPR regimes in many countries including Canada (e.g. the Plant Breeders Rights in 1990). At the same time public research institution have been asked to adopt a collaborative rather than a competitive approach with private research institution (Gray et al., 2000b). As a result a shift has occurred in the funding of canola research. Gray et al. (2000b) show how over the period 1944-1985 public research accounted for 68% of total research on canola in Canada. Over the period 1985-1998 the share of public research had fallen to 41%. Until 1985 almost all the canola varieties available in Canada were developed by public institutions, while at present the opposite is true (figure 3).

What are the effects of privatisation of R&D on the development of new varieties? Spence (1976) and Beath and Katsoulakos (1991) show how the market is biased against products with low demand elasticity and high fixed costs. This is because even if a product is socially desirable it might be unprofitable. Unless perfect price discrimination is possible the profit will not capture all the consumers' surplus. The difference between total surplus and profit will be larger the higher the fixed costs and the more inelastic is the demand. It is therefore possible for a product with lower price elasticity to have lower profits and higher net surplus than a product with high price elasticity. In such circumstances the product with the higher elasticity will be produced. On the other hand given two products with a similar demand elasticity but different cost structures (e.g. one product has lower marginal costs and higher fixed costs), it is possible for the product with lower fixed costs to be produced because of the higher profits associated with it (despite the fact that the product with low marginal costs would have generated a larger net surplus). The market is biased against products with high fixed costs and inelastic demand.

B. rapa was likely to be characterised by inelastic demand, because it represented a lower yielding variety (on average) particularly suited to the dry conditions of certain parts of Saskatchewan and Alberta.*B. rapa* was certainly unprofitable after 1994. All the private breeders cut their research on *B. rapa* at that time.

Figure 3 : % of canola acreage planted with varieties developed by Public Research



Source: extrapolated from the Prairies Pools Surveys (1972-1989) and the Prairies Grain Variety Surveys (1990-2002)

Today the only interest in improving these varieties and developing new ones (e.g. *B. juncea*), in order to diversify canola production, lies in the public institution and growers associations (Dr. Rakow and Dr. Falk, AAFC Saskatoon Research Centre, personal communication).

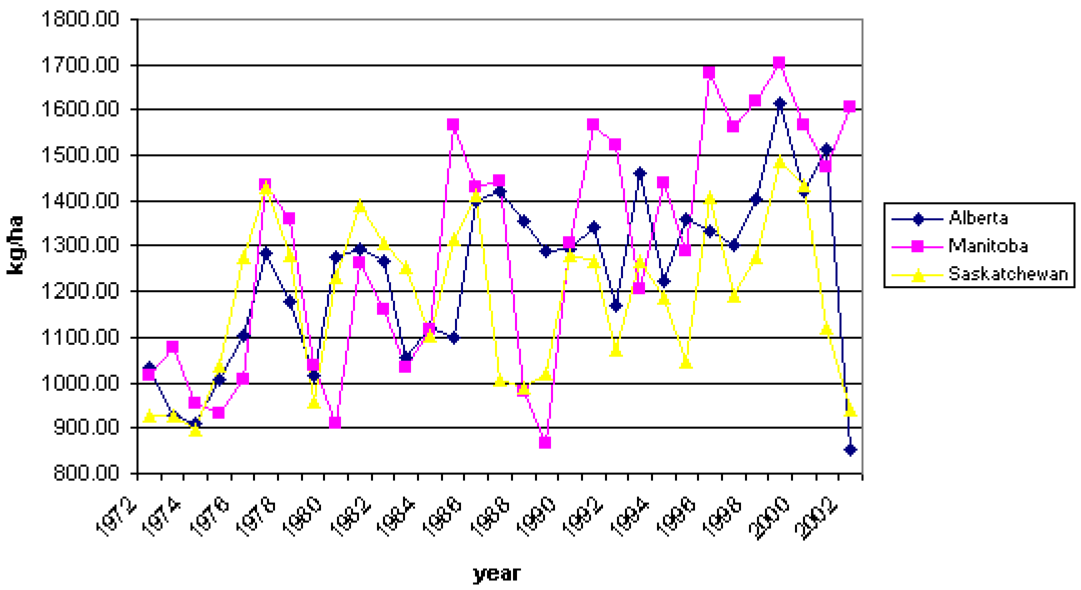
However, one question remains: despite being unprofitable, is a higher degree of interspecific diversity (*B. rapa* and *B. napus*) in the canola crop desirable? In order to answer this question an analysis of the effects of interspecific diversity on the productivity of canola in Western Canada is conducted.

5 The productivity of canola: a mean-variance approach

In the previous sections we have discussed how the changes in the structure of the seed industry and the privatization of R&D activities for the development of new crop varieties have crucially affected the set of commercial canola varieties available to farmers, leading to the spread of a single canola species (i.e. *B. napus*). In this section our aim is to briefly investigate the effects of such specialization on the productivity of the canola crop.

The effect of within crop diversity on agricultural production has been analysed in the past (e.g. Smale et al., 1998). Crop diversification can improve pest management and can provide a buffer against adverse climatic conditions. On the other hand specialisation usually occurs in order to increase average returns. In the Canadian case, the rush towards specialization was probably driven more by factors operating on the supply side (i.e. the structural changes in the seed industry discussed above). In what follows a mean-variance analysis of the canola yield over the period 1972-2002 in the prairie provinces of Canada (Alberta, Manitoba and Saskatchewan) has been conducted. Data on crop yield (figure 4), fallow area (figure 8), fertiliser consumption (figure 6) and fertiliser prices were obtained from Statistics Canada (CANSIM).

Figure 4: Canola yield in Western Canada



Source: Statistics Canada (CANSIM)

Data on average output prices were obtained from Agriculture and Agrifood Canada (AAFC) Market Analysis Division (Winnipeg). Data on rainfall and temperatures during the growing season were obtained from Canada Climate. Data on HT varieties adoption and within crop diversity (figure 5) were extrapolated from the Prairies Pools Surveys (1972-1989) and the Prairies Grain Variety Surveys (1990-2002) data obtained through the Canadian Grain Commission.

5.1 Methods

Drawing on Just and Pope (1978) we use a stochastic production function with multiplicative heteroskedasticity, that is

$Y = f(X, \alpha, \beta) + g(X, \delta)u$ (4.a)

and $E(u) = 0$, $Var(u) = 1$ (4.b)

where
Y: yield ; X : inputs ;alpha,beta, delta : parameters

Given expressions (4.a) and (4.b) we know that

$E(Y) = f(X, \alpha, \beta)$ (5)

and $Var(Y) = g^2(X, \delta)$ (6)

In this case expression (4.a) is a simple regression model with multiplicative heteroskedasticity and can be estimated by using a three-step approach (Wooldridge, 1999). First we estimate model (5) by ordinary least squares (OLS). Second we use the residuals to estimate $g^2(X, \alpha)$. Third we estimate the model by generalised least squares (GLS) using the estimated $g^2(X, \alpha)$as weighting variable.

The production function in (5) is specified as follow

$Y = K \times \overline{N}^{\beta_1} \times Area^{\beta_1}$ (7.a)

$$K = \exp\begin{bmatrix} \alpha_0 + \alpha_1(rain) + \alpha_2(EMaxT) + \alpha_3(EMinT) + \alpha_4(Div) \\ + \alpha_5(DEMinT) + \alpha_6(HT) + \alpha_7(Time) \end{bmatrix} \quad (7.b)$$

where

Y: yield (kg/ha); *N*: nitrate (kg/ha); *Rain*: rainfall in the growing season (mm); *EMaxT:* Extreme maximum temperatures in the growing season; *EMint:* Extreme minimum temperatures in the growing season; *Div*: Shannon Index of interspecific diversity (*napus* vs. *rapa*); *DEMinT*: *Div ´ EminT*; *HT*: % of canola acreage planted with HT varieties; *Area:* total canola crop acreage; *Time:* time index (proxy for technological development).

The dash over the variable (N) indicates that nitrate application is estimated by taking into consideration input/output prices and fallow (figures 10, 11 and 12). The following relationship is then estimated

$$N = \gamma_0 + \gamma_1\left(\frac{ep}{w}\right) + \gamma_2(pfallow) + \varepsilon \quad (8)$$

where

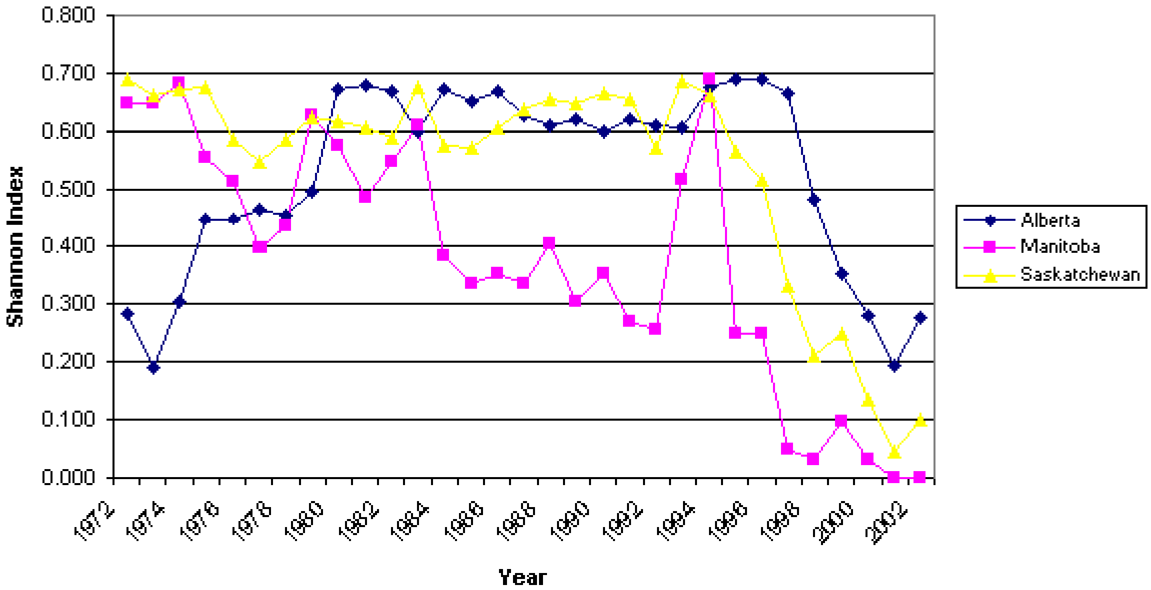
N: nitrates application (kg/ha); *ep*: expected crop prices; *w*: fertilisers prices; *Pfallow*: percentage of agricultural land under fallow.

The predicted values in expression (8) are then used as regressors in expression (7.a).

Finally, drawing on Wooldridge (1999) we specify g^2 is as follow

$$g^2(X,\delta) = \exp\left(\sum \delta_i x_i\right) = \exp\begin{bmatrix} \delta_1(Div)^2 + \delta_2(rain) + \delta_3(EMaxT) + \delta_4(EMinT) \\ + \delta_5(DEMinT) + \delta_6(\overline{N}) + \delta_7(HT) + \delta_8(Area) \end{bmatrix} \quad (9)$$

Figure 5: Interspecific Diversity based on the acreage of *B. rapa* and *B. napus*

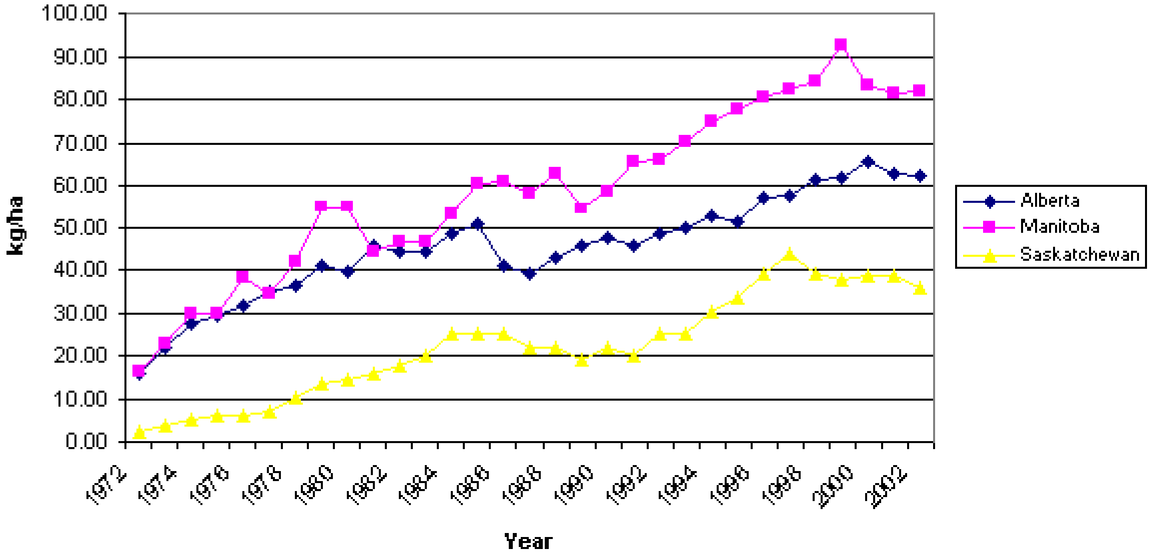


Source: extrapolated from the Prairies Pools Surveys (1972-1989) and the Prairies Grain Variety Surveys (1990-2002)

The predicted values from regression (9) are then used to create weights to correct the heteroskedasticity in regression (7.a) through a GLS estimator (Wooldridge, 1999).

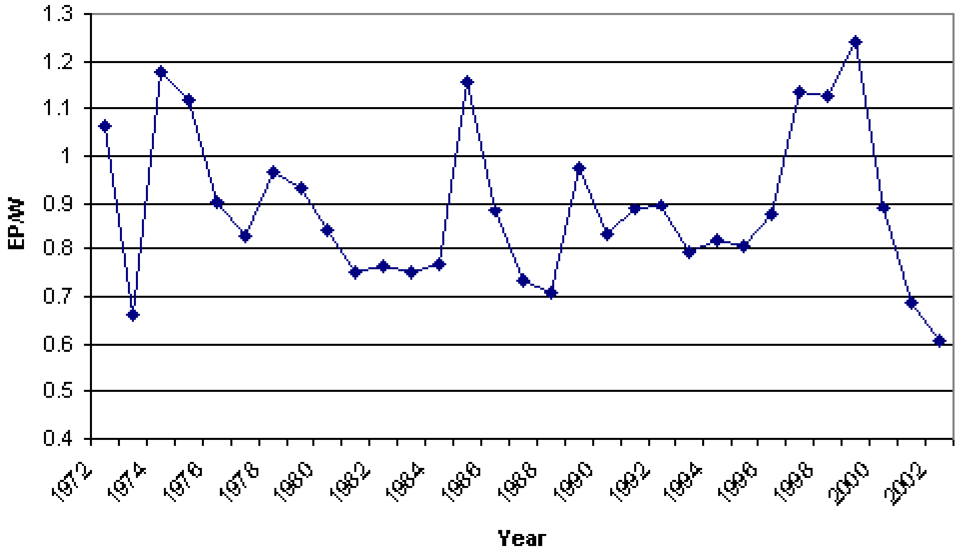
All the econometric analysis is performed by using Limdep version 7.0.

Figure 6: Nitrate consumption in Western Canada



Source: Statistics Canada (CANSIM)

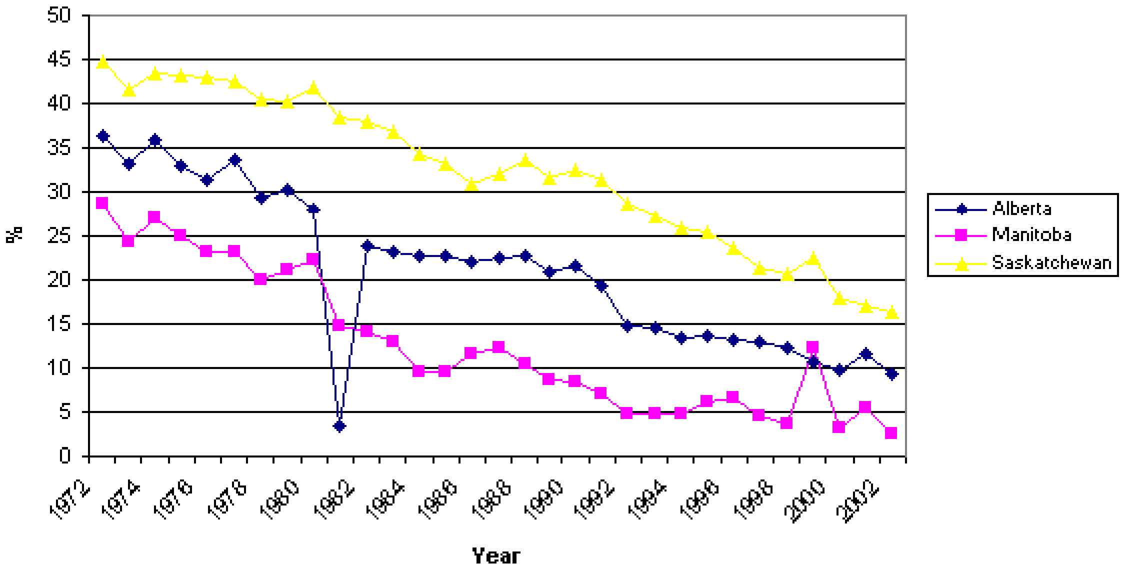
Figure 7: Normalised output price index



EP(1995)=100; W(1994)=100.

Source: AAFC Market Analysis Division and Statistics Canada (CANSIM)

Figure 8: Percent of agricultural land in summer fallow



Source: Statistics Canada (CANSIM)

5.2 *Results*

NITRATE DEMAND

Expression (8) is estimated by using a GLS estimator (table 3). The results show how nitrate consumption is positively affected by an increase in normalised prices (e.g. through an increase in expected output prices and/or a decrease in fertilisers prices) and it is negatively affected by the fallow area. When first-order autocorrelation is taken into account, however, the effect of prices becomes insignificant.

Table 3: Estimation of Nitrates demand

	GLS	*GLS (AR1)*
Constant	70.932***	68.995***
EP/W	8.490*	4.869
% fallow	-1.666***	-1.431***
Rho	0.51673	0.607***
DW	0.96655	2.08920
Adj. R^2	0.88069	

*** significant at 1% level; ** significant at 5% level; * signicant at 10% level.

CANOLA PRODUCTIVITY

A) The mean yield: OLS estimation

Expression (7.a) is initially estimated through OLS. The results show some interesting facts (table 4). The effect of extreme climatic event is made clear: indeed very high and very low temperatures are detrimental to the crop yield. Interspecific diversity (*napus vs rapa*) on its own does not affect the yield. On the other hand, greater diversification is significant when jointly analysed with extreme low temperatures. The negative sign on (DEMINT) suggests that the lower the extreme minimum temperature the more diversification will buffer yield losses.

B) Yield Variance

Expression (9) is estimated through GLS, in order to correct for heteroskedasticity. The results confirm that increasing interspecific diversity (*napus vs rapa*) leads to a reduction in yield variability (i.e. portfolio effect). This conclusion is strengthened by the sign of the coefficient associated with the variable (*DEMINT*): the benefits of diversity in mitigating yield variability will be larger when very low temperatures occur. The variability of the yield seem to increase with rain and extreme high and low temperatures. The application of nitrate has a stabilising effect on the yield.

C) The mean yield: GLS estimation

At this point a GLS estimator is used in order to correct the OLS estimation of expression (7.a) from heteroskedasticity (GLS in Table 4). The variables (*EMAT*) and (*EMINT*) are jointly significant (F-Test, p=0.0013). As before very high and very low temperatures have a detrimental effect on the yield. The effect of interspecific diversity is evident when it is combined with extreme low temperatures (*DEMINT*). The negative sign on the coefficient associated with (*DEMINT*) suggests that the lower the extreme minimum temperature, the more diversification will buffer yield losses. The effect of nitrate also seem to be negligible. This might appear strange. However the efficacy of nitrogen fertilisers is strongly constrained by the availability of moisture in the soil.

The low value of the Durbin-Watson statistics suggests that the model might be affected by autocorrelation. We use the Cochrane-Orcutt algorithm within Limdep to correct the first-order autocorrelation (see model GLS (AR1)) in Table 4). The main difference with the model above refers to the effect of crop acreage and HT traits. Both these variables seem now to exert a negative effect on yields. The negative sign on the coefficient associated with the crop acreage suggests that: a) when the crop area is expanded less productive land is brought into production; b) when the crop area is expanded less experienced farmers might be involved. The time trend shows a positive sign.

Table 4: Analysis of canola productivity

Variables	*Log[Mean Yield] (OLS)*	*Log [Yield Variance] (GLS)*	*Log[Mean Yield] (GLS)*	*Log[Mean Yield] (GLS) AR(1)*
Constant	8.4772***		7.226***	8.292***
Rain	0.0012	0.029**	0.003**	0.002*
EMaxT	-0.032***	0.341***	-0.013†††	-0.028***
EMinT	0.089***	-1.61***	0.067***	0.087***
DEMinT	-0.124**	2.998***	-0.08**	-0.12**
Log (N)	-0.073		0.024	-0.05
Log (Area)	-0.072*		-0.027	-0.08*
Time	0.018***		0.012***	0.016***
HT	-0.003**	0.017*	-0.0016	-0.0028**
Div^2		-8.321***		
N		-0.025*		
DW	1.40236	2.27768	1.32319	2.06719
Rho	0.29882	-0.13884	0.33840	0.33840
Adj. R^2	**0.40686**	**0.23224**	**0.61982**	

* significant at 10% level. ** significant at the 5% level. *** significant at the 1% level. † Jointly significant with EMinT at 10% level. †† Jointly significant with EMinT at 5% level. ††† Jointly significant with EMinT at 1% level.

6 Discussion

From the analysis presented above we can draw some interesting conclusions. First, the yield of the canola crop in Western Canada is certainly affected by climatic conditions during the growing season. Second, the degree of interspecific diversity (*B. napus* and *B. rapa*) also plays an important role in explaining the average crop yield. Indeed, increasing diversity does not necessarily reduce average yield, because of the buffer effect in the event of drops in the temperatures. For the same reasons increasing diversification seems to exert a stabilising effect on average canola yield. Third, the claim that HT technology increases the yield has to be handled carefully. Indeed, despite the large diffusion of HT varieties in Western Canada it is not possible to observe a sensitive increase in the yield of canola (Figure 4). The main reason behind the large scale adoption of HT canola varieties is the easiness of weed control (not the improved yields).

The main goal of this paper has been to investigate the effects of structural changes in the seed industry on canola productivity. The surge of agro-biotechnology has led to a sharp consolidation in the seed industry among few multinational players and to a sharp decline in publicly funded research for the development of new varieties. Both institutional changes have affected the development of canola varieties. In Canada, we have seen how the main consequence of industry consolidation and R&D privatisation have been a sharp reduction in investments towards the provision of different varieties like *B. rapa*. This might reflect a technological lock-in. Interest in diversifying the canola crop (e.g. through the improvement of *B. rapa* and/or the development of other brassicas varieties like *B. juncea*) is confined to public institutions and growers associations (e.g. AAFC). On these basis higher public support towards R&D activities aiming to develop of different canola varieties is warranted.

The implications of the trend for Developing Countries (DC) is also interesting. It is well known that agro-biotechnology multinationals are pressing to introduce the technology in DC (e.g. Africa). In order for the Governments of these Countries to make an appropriate decision it is important that they fully consider: a) the institutional changes that might follow in their seed industry and b) the impact on the development of crop varieties. The consequences associated with the loss of local varieties could be much dearer in poor Countries, where germplasm conservation is extremely difficult.

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