Canada – U.S. Pesticide Regulation:

An Economic Analysis of Price Discrimination

Agriculture and
Agri-Food Canada

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Canada

CANADA – U.S.
PESTICIDE REGULATION:
An
ECONOMIC ANALYSIS
of
PRICE DISCRIMINATION

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December 2004

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Strategic Research
Agriculture and Agri-Food Canada

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Publication 53261786B
ISBN 0-662-38727-9
Catalogue A38-4/1-2004E-PDF
Project 04-037-r

Aussi disponible en français sous le titre :
« Réglementation des pesticides au Canada et aux États-Unis : une analyse économique de la discrimination des prix »

TABLE OF CONTENTS

TABLE

FIGURE

FOREWORD

AAFC has monitored pesticide prices on both sides of the border for many years because pesticide pricing has been a perennial issue. Canadian farmers have more recently been concerned with pesticide availability. In May 2003, the Government of Canada committed $54.5 million over six years to provide faster registration, which will improve the availability of minor-use and reduced-risk pesticides and help Canadian producers. U.S. farmers, particularly in North Dakota, have complained that they face higher prices than Canadian counterparts, which led to a proposal to allow farmers to import pesticides for their own use from Canada. Although this legislation was not adopted, the issue of cross-border differentials in pricing and availability is an on-going irritant.

The Pest Management Regulatory Agency in Canada and the American Environmental Protection Agency have been increasing regulatory cooperation through the NAFTA Technical Working Group on Pesticides with the goal of a North American market for pesticides. They have approached harmonization through agreements on work sharing and the creation of a joint application process and have begun work on a common “NAFTA label” that would be used in all three countries.

Patent protection and pesticide regulations confer market power, which firms can use to recoup the cost of product development and registration. This report first evaluates cross-border differences in pesticide pricing and availability, taking into account this market structure, to determine whether current plans for regulatory harmonization will likely result in harmonized prices and availability. Secondly, it evaluates the consequences of effectively eliminating cross-border price discrimination for pesticides in terms of the impact on pesticide prices and use and the welfare of farmers on both sides of the border.

The international component of the Agricultural Policy Framework (APF) is designed to maximize international opportunities arising from progress on the domestic front. This report illustrates some of the most complex issues involved in our relationship with our most important trading partner.

EXECUTIVE SUMMARY

Pesticide regulation has important implications both for the regulatory process in general and for agricultural conditions. Country-specific regulation of pesticides to preserve human health and environmental quality has the unintended consequence of creating a perfect mechanism to prevent cross-border arbitrage and allow price discrimination.[1] Pesticide price differentials have fueled interest by U.S. farmers to import Canadian pesticides while Canadian farmers are concerned that some pesticides used by American competitors may not be available in Canada. Concerns with pesticide market structure and regulation together with evidence for price discrimination are summarized in this report, with an analysis of the impacts of eliminating price discrimination for four specific pesticides.

In general, the design and management of the regulatory process in Canada and the U.S. has not been concerned with either the impacts on pesticide manufacturers pricing strategies or the effects on farmers profits and production opportunities from differences in access. Regulatory cooperation in North America has been largely focused on the objective of harmonization under the assumption that this will provide uniform benefits to all customers and possibly to manufacturers. The logic of this argument comes from an expectation that harmonization will reduce the costs of registration but the pass-though of these benefits depends on whether the markets for pesticides are competitive or not. The consequences of regulatory change, therefore, could include some unintended adverse consequences, especially in Canada.

Patent protection is a barrier to entry and allows patent holders to maximize returns by setting prices above marginal costs. Many pesticides currently benefit from patent protection. Pesticide regulation provides a further barrier to entry and, since pesticide registration is use-specific, a means of market segmentation. Market segmentation in turn allows cross-border price discrimination that results in systematic price patterns in different market segments—patterns unrelated to costs specific to the market segment.

The existence of persistent price differentials for pesticides has been studied for some time [Carlson, McEwan and Deen, McEwan and Deen, Taylor and Koo, Taylor and Gray]. It is shown here that price differentials for some pesticides are significantly different between Canada and the U.S. but there are no significant differences in pesticide prices in markets studied within each country. Furthermore, the prices of some pesticides are systematically significantly higher in the U.S. while the prices of other pesticides are systematically higher than those in Canada. Although several alternative hypotheses were considered, only price discrimination is consistent with the price patterns seen in these data. Given that price discrimination is a widely practiced pricing strategy, the conclusion that price

1. *There has been wide-spread attention recently to a very similar process that encourages imports of lower-priced prescription drugs from Canada by American consumers, thereby weakening a long-standing price structure that favored Canadians.*

differentials are indeed a result of price discrimination is therefore warranted.

Complaints of various farm groups that free trade should mean uniform prices at the retail level have resulted in some attempts to effect changes to promote pesticide uniform prices. Most notably, Dorgan, Baucus and Conrad introduced legislation in the U.S. Senate to allow farmers to import pesticides for their own use from Canada. The objective of this legislation appears to be supported by the regulatory bodies responsible for pesticides in the NAFTA area whose joint objective is to create a single market for pesticides in North America.

However, the consequences of creating a single market do not appear to have been evaluated. In this paper, the effects of eliminating market segmentation of four pesticides (Glyphosate, Fenoxaprop, Clopyralid and Sethoxydim) sold in both Canada and the U.S. are estimated. Results are given for both the change in price and quantities of the pesticide sold in each country, for total sales in both countries, profits of the pesticide manufacturer and the welfare of farmers who use the pesticide (as measured by the consumer surplus areas under their demand curves) on both sides of the border.

The market equilibrium condition for a firm facing downward sloping demand functions in two or more market segments can be used to calibrate demand functions for certain functional forms using only observations of prices and quantities in each market and marginal cost. Estimates were made of prices and quantities of the four pesticides on both sides of the border. The price of Sethoxydim is higher in Canada while the prices of the other three pesticides are higher in the U.S. Marginal costs are not known but they must lie between zero and the lower of the prices observed in Canada and the U.S. Demand functions were therefore calibrated with marginal costs varying in increments of 10% over the range 20 – 80% of the lower observed price for each of the four pesticides. The demand functions were then solved to maximize manufacturer returns under the condition that prices were the same in both markets. The exercise was repeated with linear and a non-linear functional forms for the demand functions.

In all cases, the equilibrium price without price discrimination is found to be close to the American price because of the larger size of that market. Demand elasticities are greater than unity for a monopolist and the equilibrium condition for price discrimination implies that demand elasticities are higher in absolute terms in the market segment with the lower price. As a result, we see relatively large price changes (increases for Glyphosate, Fenoxaprop, Clopyralid, and decrease for Sethoxydim) for Canada and corresponding large changes in quantity demanded. Under some, perhaps extreme, assumptions about functional form and marginal cost, demand in Canada is reduced to zero because the resulting price exceeds the highest price Canadian farmers would be willing to pay. Profits to the manufacturer are always lower and total quantity produced is always lower for the non-linear demand functions.

Table 1 shows the welfare changes that result from the elimination of price discrimination for each of the three principal agents in the market. The models show that even though aggregate welfare from changing to a uniform price from price discrimination, or vice versa, is small but the components that accrue to farmers in each country or to pesticide manufacturers can be large. The distribution of winners and losers and their magnitudes are very consistent across values assumed for marginal cost and the functional form used for the demand function.

On the other hand, total welfare changes are relatively small and sensitive to assumptions about marginal cost. The variation in total welfare gains includes change in sign with the linear demand function. Total welfare increases with the elimination of price discrimination except when the lower price market is eliminated altogether. However, with the non-linear demand function, total welfare decreases for Glyphosate, Fenoxaprop and Clopyralid but increases with Sethoxydim.

TABLE 1

Change in consumer surplus with marginal cost at 20% and 80% of the lower observed price ($US million)

	Canadian farmers		U.S. farmers		Pesticide company*	
	20%	80%	20%	80%	20%	80%
LINEAR DEMAND						
Glyphosate	-17.7	-5.4	47.6	0	-20.0	-10.7
Fenoxaprop	-9.9	-3.2	23.5	0	-9.1	-6.5
Clopyralid	-2.4	-1.1	4.5	7.4	-1.4	-4.2
Sethoxydim	9.0	10.9	-5.5	-3.0	-2.4	-5.3
NON-LINEAR DEMAND						
Glyphosate	-20.5	-9.5	28.9	4.1	-9.8	-9.9
Fenoxaprop	-11.1	-5.6	15.3	3.7	-4.6	-5.5
Clopyralid	-2.7	-1.7	3.5	1.9	-0.8	-1.4
Sethoxydim	8.8	10.5	-7.0	-5.3	-1.6	-3.0

* In some instances, slightly higher values occur for values of marginal cost between 20 and 80%.

Finally some conclusions may be drawn from this particular example that may be applicable in many of the other markets subject to price discrimination:

- The standard assumption found in intermediate microeconomic texts is that eliminating price discrimination leads to increases in welfare is generally true only for linear demand functions, and only if the interests of individuals in each market has equal weight in the social welfare function.

- Since the new market price when discrimination is eliminated is bounded by the two prices prevailing under discrimination, some individuals will be net loses. For aggregate welfare to increase there has to be a larger increase in welfare in the market that experiences the price decline than the sum of the loss in welfare in the market where price increases and the lost profit for producers. Importantly, moving from price discrimination to a uniform price always results in both winners and losers.

- Because price discrimination is more profitable than charging a uniform price, there is a stronger incentive for firms to participate in the market. If in the long run profit margins are not particularly strong, even under price discrimination, then removing the increment of profit that comes from discrimination can alter longer run incentives to participate in specific markets.

- The specific nature of the demand functions has a great impact on the distribution of welfare gains and losses associated with imposing a uniform price. Once a linear demand function is abandoned it is unlikely that output will be invariant when moving from price discrimination to a uniform price. Even assuming social welfare functions that impose equal weights on individual welfare being in place, it is still possible with some fairly simple functional forms to show price discrimination is socially desirable.

The case of pesticides also has some interesting implications of how the benefits of freer trade and regulatory harmonization may be distributed.

- Clearly, free trade is not sufficient to create a single market for products like pesticides. It will always be in the producer's interest to maintain market segmentation and price products according to differences in demand elasticities so segmented markets for these commodities are likely to persist unless consumers have the right to import freely from other countries in the free trade area.

- Many of the benefits of regulatory harmonization should reduce compliance costs and other fixed costs. The benefits of these changes are likely to be captured by the manufacturer at least in the short run. The benefit to the consumer will be in the form of a wider range of suitable products available in the market. Consumer benefits will be realized only when greater competition from a wider range of products results in more elastic demand functions for each product.

At the most general level the implications of the analysis for pesticide policy are significant. It suggests that the social welfare implications of change are complex, both in terms of short terms static effects on different groups and in terms of the longer run dynamics of the industry. There has always been a recognition that harmonization of pesticide regulation may not be desirable. The main argument in the past has been that there may be sound environmental and public policy differences that require the markets be treated as distinct entities. Our work also confirms that domestic policy interests can provide an additional reason for maintaining distinct markets if one party is a net loser. However we also raise the possibility that price discrimination may provide a higher level of aggregate welfare than is the case if prices are set at a uniform level.

SECTION 1
THE ROLE OF PESTICIDES IN FARM PRODUCTION

Pesticides are a class of compounds used in agriculture to enhance the quality and/or quantity of desirable species of plants or animals. Pesticides control pests by either killing or weakening them, or by making the treated product unattractive to the pest. Pests take the form of animals, insects, plants, fungi and nematodes, but the defining feature of a pest is that it causes an adverse effect upon some species of plant or animal that the farmer is trying to produce.

While natural forms of pesticides have been employed since the very early stages of agriculture, pest management took on new significance following World War II as advances in chemistry and biology combined with the mechanization of agriculture and the wide spread use of synthetic fertilizer to transform production technology. The USDA estimates that 86 percent of the acreage planted to five major crops (wheat, corn, cotton, soybeans and fall potatoes) were treated at least once with a herbicide (USDA 2000, p. 19). Of these crops, cotton made the most use of all forms of pesticides and wheat the least. Other USDA analysis shows that fruits and vegetables have far higher per acre use rates and employ a broader spectrum of pesticides (USDA 2001, p. 13).

Table 2 demonstrates the importance of pesticides for the production of some major crops world wide. Crop production without pesticides would result in lower yields, greater field and post harvest losses and declines in the quality of product that would lead to a reduced supply of food and fiber and consequently higher prices. As a result, there would be some combination of a significant reduction in food production or expansion of land under cultivation (Oerke et al). Expanding the area cultivated would bring its own problems in the form of lost species habitat and increased levels of erosion. Finally, cultivation practices would have to return to more intensive use of plows, discs and harrows, all of which require increased outlays on tractor fuel and increased soil compaction.

Pesticide expenditures are a relatively small share of total input costs for most farmers. However they play a more significant role than their share of production costs would suggest. Fox and Weersink describe pesticides as part of a group of inputs that provide damage control. Their value in the production process is indirect in the sense that they limit the effect of adverse conditions on the production process. This means the marginal value of the damage control input depends upon the conditions that prevail. In some circumstance, few pests, the marginal value product of pesticides is small. In other circumstance, many pests, it is high. Importantly decisions about pesticide application typically have to be made without good information about pest incidence.

Another critical factor in the process is that application rates are not continuous. There are legal maximum quantities of each pesticide that can be applied. Exceeding these levels can lead to legal problems for the farmer or applicator. In their paper, Fox and Weersink suggest that there are often increasing returns from applying pesticides up to some ceiling (either the maximum allowable rate or a rate that achieves complete control). This means that profit-maximizing farmers will often either apply the ceiling rate or no pesticides (Fox and Weersink, p. 38).

In summary, although pesticide prices are a small share of total production costs, they have a great bearing both on short run quality and quantity of output and, in the long run, production technology available to farmers. This means that the price, and more importantly the availability, of pesticides could greatly influence the economic position of much of the farm sector.

TABLE 2

Impact of pesticides on production of major crops

Crop	Theoretically attainable production	Actual production (avg. 1990-98)	Estimated production without crop protection	% decline in production without crop protection	% increase in land to restore actual output
Rice (mt)	1047	509	184	64%	280
Wheat (mt)	831	548	400	27%	140
Barley (mt)	244	172	129	25%	130
Maize grain (mt)	729	449	295	34%	150
Potato (mt)	464	273	123	55%	220
Soybeans (mt)	152	103	63	39%	160
Cotton (kt)	84.1	52.4	13.9	74%	380
Coffee (kt)	9.8	5.9	3.0	49%	200

Source: E-C Oerke, H-W. Dehne, F. Schonbeck, and A. Weber. Crop Production and Crop Protection Estimated Losses in Major Food and Cash Crops. Amsterdam: Elsevier Science B. V. [1994]

SECTION 2
THE REGULATORY PROCESS

Pesticides have significant costs inherent in their use. Because they are toxic by design, they can harm non-target species, including applicators, bystanders and wildlife. Pesticide residues can become embedded in food products with possible harmful effects for consumers. There has therefore been an increasingly important regulatory role governing the use of pesticides.

The concern in this paper is with the regulation of which pesticides are deemed acceptable to use and their allowable uses. Pesticides are regulated first by patent law which establishes the property rights of the inventors of each new pesticide product and then by regulations which, in effect, licenses each allowable use of a pesticide. An allowable use includes the crop on which it may be used, application rates and other restrictions on how it may be used. The product label is closely proscribed by regulators in each country so that it provides each pesticide applicator with the information necessary to comply with the regulation.

2.1 Evolution of the regulatory structure

There have been significant changes in the regulation of pesticides over the last fifty years, including a shift in the focus of regulation form efficacy to safety and a change in the primary regulatory agency from departments of agriculture to agencies more focused on human and environmental safety.[2] Both the U.S. Environmental Protection Agency (EPA) and the Pest Management Regulatory Agency (PMRA) of Health Canada are charged with protecting human well-being, wildlife and natural habitat. Both governments use essentially the same process to register pesticides for each allowable use, except that Canada still requires efficacy testing. Consequently, the impacts of pesticide regulation on farm profitability and the competitive position of agriculture are at best secondary elements in the decision process of both countries.

While both Canada and the U.S. have each operated independent regulatory systems, there has been a longstanding process of collaboration at the agency level. As the scientific basis of regulation increased it became obvious that there was considerable potential to share scientific expertise and divide the analytical portion of the regulatory function between the two countries. In turn this led to the establishment of common data packages to facilitate the regulatory process. It should be noted that this did not mean that interpretation of the data results was always the same. One of the more notable examples of divergent interpretations was the decision by Canada in the early 1980s to ban the herbicide Alachlor due to a fear of possible carcinogenic effects, while the U.S. drew the conclusion that Alachlor was safe from the same data (Shapiro et al.).

The introduction of NAFTA led to the formation of the NAFTA Technical Working Group (TWG)

2. *Freshwater and Short and Freshwater provide an overview of recent regulatory changes in Canada and the U.S. and the role of NAFTA and a discussion of stakeholder interests in the evolution of the system.*

on Pesticides to provide a forum to better integrate regulation of pesticides. The TWG includes representatives of the Comisión Intersecretarial para el Control del Proceso y Uso de Plagicidas y Sustancias Tóxicas Mexico as well as the EPA and PMRA. A main focus of the TWG is to ensure that common scientific standards are followed, coordinate the analysis of registration data and resolve potential trade irritants such as differences in maximum residue limits (MRLs). The TWG has clearly articulated goals of harmonization and working toward creating a North American market for pesticides in which "growers in all three countries can access the same pest control tools." It has approached harmonization through agreements on work sharing and the creation of a joint application process that includes a common data submission and format and a coordinated review process. The working group has begun work on a common "NAFTA label" that would be used in all three countries.

Joint submissions may provide a significant step in reducing the cost of approval for new pesticides. Pesticide manufacturers have the option of submitting proposals for allowable uses to individual governments or jointly. A company may still wish to pursue individual submissions in both countries if they would like to market a compound differently with regard to concentration, application method, etc. Assembling the data required for registration for three packages is both time consuming and expensive. Besides reduced compliance costs, joint submissions are expected to be given higher priority, reducing the time required to obtain a decision. Work sharing offers the potential of considerable cost saving on the part of the regulatory agencies. Each nation takes a piece of the data in a given registration package and performs an evaluation that will be accepted by the other parties.

With a common label, issues of own use importation could largely be resolved. Because the single label would be legal in each country, there would be no reason to prevent a farmer from crossing the border to purchase a specific chemical. Note that a common label does not have to mean that all uses or application rates must be standard. While a farmer in one country could purchase a product that had a common label, it could only be used for those purposes, and at those rates, that were legal within that country. In particular, differences in environmental impacts on non-target species could still make some uses possible in one country but not in another.

2.2 The link between regulation and market power

As indicated above, regulatory approval is a costly process similar, from an economic point of view, to the research needed to invent the pesticide. In addition to establishing patent rights, the pesticide manufacturer has to undertake scientific studies to demonstrate the safety of each proposed allowable use of the pesticide. Besides the compliance costs of undertaking these studies and preparing the submissions for regulatory approval, there are not inconsequential application fees and additional costs imposed in the time required to obtain approval. The registration of a pesticide for a particular use is an intellectual property of the manufacturer registering the pesticide. If a pesticide is no longer eligible for patent protection, other manufacturers must independently incur much the same cost to obtain the right to sell the product for each use. Rights to sell a pesticide for a specific use are therefore, another barrier to entry over and above patent protection.

Some pesticides have been removed from use in response to our greater understanding of their unintended consequences. Other pesticides are less effective because species evolution in the target pests has resulted in greater resistance. However, the search for effective but safe pest control products has become more difficult over time due to governments setting more stringent limits on acceptable risks and the simple fact that we have made most of the easy discoveries.

In the last decade, both Canada and the U.S. implemented major legislative changes in pesticide regulation. In the U.S., the *Food Quality Protection Act* (FQPA) of 1996 significantly changed the way pesticides were regulated. The major elements of FQPA were: the repeal of the Delaney Clause to allow the presence of carcinogenic compounds in food if the level of presence is considered to pose no risk; the creation of a new standard for assessing exposure – the risk cup– that looks at all pathways of human exposure to classes of compounds instead of focusing on exposure on a compound by compound basis; explicit attention to the possibility that infants and children may have more adverse consequences from a given level of exposure than adults; creation of a relatively short time-line for reassessing the registration status of all licensed pesticides using current standards and the elimination of economic benefit as a factor in the registration decision. The *Pest Control Products Act* that received Royal Assent in December 2002 makes many of the same changes in Canadian pesticide regulation.

One consequence of the FQPA has been a focus on two broad classes of compounds, organophosphates and carbomates that are widely used ingredients in insecticides used on major field crops, fruits and vegetables. In many cases, there are no obvious substitutes for insecticides based upon these materials and there is a concern that if these products are de-licensed there could be significant impacts on production.

The development of pesticides has become an increasingly expensive process and the number of firms engaged in agricultural biotechnology has declined significantly in recent years (King, p. 1). Patent protection and the registration process provide an incentive for firms to engage in the risky and expensive process of developing new compounds. Brown and Gruben (p. 18) show that property rights provide a strong incentive to restrict supply in a way that extends the useful life of the compound. However such protection clearly creates monopoly power for pesticide producers and it is important that efforts to examine the industry recognize the existence of this monopoly power.

The analysis of Fox and Weersink suggests that pesticide producers should have considerable pricing power, especially where there are few close substitute compounds. The cost of switching to alternative non-chemical control technologies (for example, crop rotations or more tillage operations) may be high. Similarly King's argument that concentration is increasing in the agricultural biotechnology industry suggests that competition may be lower than it was in the past.

In addition to creating a basis for market power, the regulatory system provides an incentive for cross-border market segmentation. The demand for a pesticide will be the sum of the demands for each registered use of that pesticide on both sides of the border. The demand for each allowable use will depend on competition from good alternative pesticides and these vary from country to country. For example, Carlson, McEwan and Deen report that only half of 54 herbicides approved for wheat in Canada and the U.S. are registered for wheat in both countries. Two of the most significant herbicides used for wheat in the U.S are not registered in Canada and five of the most significant pesticides registered in Canada are not registered in the U.S. They have similar findings on registration for other types of pesticides and other crops.

Resulting differences in demand have implications for the optimal marketing strategies on either side of the border. Naturally it will be most profitable to register a pesticide in a market segment where demand is stronger and where substitutes are less satisfactory.

Other factors may contribute to differences in demand elasticity on either side of the border. The different crop mix and even potential non-agricultural uses may also be important to the overall demand for each pesticide in each country. Government support programs differ across the border in terms of the crops eligible for support, the amount of support provided and how support is coupled to farming. Differences in other input prices (labour, land, interest rates, fuel, etc.) and taxes may affect demand elasticity and therefore the optimal pricing policy.

The regulatory system also provides a means of segmenting markets. Preventing arbitrage among different allowable uses in Canada, for example, is not really possible so there may be a single market for each pesticide within each country. But even products which are licensed in both countries can not be imported by pesticide users because they do not have the labels specifying the allowable use in the importing country. Cross-border arbitrage is not possible, so pesticide manufacturers can follow different pricing policies in each country. An optimal marketing strategy would recognize cross-border differences in demand and the opportunity presented by market segmentation to set prices in each market that equated marginal revenue with marginal cost.

SECTION 3
PESTICIDE AVAILABILITY AND PRICING ISSUES

Since farmers in Canada and the U.S. remain competitors in North American or world markets there is considerable concern that the playing field is level for critical inputs such as pesticides. From their perspective, the two critical issues are first, access to the same spectrum of pesticides as farmers in competing countries and second, equivalent prices for those products.

3.1 Availability issues

Several factors combine to restrict access to effective pesticides on both sides of the border. Some well-established pesticides may become less effective because of adaptation of pests. Our understanding and ability to anticipate possible negative consequences of pesticide use have become more sophisticated while our tolerance to risk and adverse environmental impacts has decreased. Regulatory changes therefore tend to reduce the options available. Old products are re-tested to ensure they meet current standards and it is more difficult to register new products. The recent introduction of the notion of the "risk cup" in which pesticides are grouped into classes with maximum exposure levels for the entire class is one such change that has important consequences for pesticide availability.

Pesticide manufacturers continue to submit both new compounds and new uses for registration but as the costs of developing new compounds may be increasing. It may be more difficult to discover new pesticides today because the easy discoveries have already been made and our lower tolerances of adverse impacts.

A considerable portion of the costs getting a new product to market are related to demonstrating that it can be safely used for each potential use. More rigorous requirements also raise the costs of registering new pesticides. The importance of the regulatory cost is perhaps best illustrated by the case of "minor uses". Governments in both Canada and the U.S. maintain programs to subsidize the registration of pesticides for markets too small to generate enough profits to cover the cost of registering the pesticide, such as "minor use" markets.

To some extent minor use status is a relative concept. For example, much of the fruit and vegetable production in the U.S. involves a minor use of pesticides relative to row and field crops like corn and wheat. But fruit and vegetable production in the U.S. still represents a large enough market that it is worth the support of chemical manufacturers. By contrast, fruit and vegetable production in Canada is both a minor market, relative to row and field crops, and small enough that the volume of sales may not be enough to warrant registering a compound for use in Canada even if it is available in the U.S. for the same crop.

Aside from the compliance costs incurred directly by the manufacturer, several different types of fees or taxes may be assessed that affect the market. From the point of view of the manufacturer, these costs might be divided into three general types:

- tariffs, sales taxes and other charges that are proportional to the quantity sold and/or price,

- annual fees and compliance costs such as those for maintaining registration, and
- one time charges and compliance costs such as those associated with establishing patent rights or the right to sell a pesticide for a particular use.

It will be profitable to place a pesticide in a particular market segment, *i*, if

[1] $PV_i = -E_i - \sum_t A_{it} e^{-dt} + \int \pi_i(t) q_i(t) e^{-dt} > 0$,

where E_i are one-time (type 1, above), costs, A_{it} are annual registration costs in period *t* (type 2, below), $q_i(t)$ is quantity sold and $\pi_i(t)$ is profits per unit both as a function of time.[3] The expenditures E_i and A_{it} are needed to create and maintain intellectual property rights to sell a pesticide in market segment *i*. They are a barrier to entry though clearly not as effective as patent rights. The effect of tariffs and taxes would also tend to reduce the profits that can be generated from a particular market segment because they reduce demand or price from the perspective of the pesticide manufacturer. It will be profitable to establish patent rights to a pesticide if the sum of the benefits across all market segments is positive i.e.,

[2] $PV_i = -E_i - \sum_t A_{it} e^{-dt} + \int \pi_i(t) q_i(t) e^{-dt} > 0$.

This is the amount that must be set against the research and product development costs incurred to invent a new pesticide.

The minor use programs increase pesticide availability by reducing E_i for the pesticide manufacturers. One of the motivations for regulatory harmonization has to be to generally reduce the burden posed by regulation on pesticide manufacturers and users. Harmonization should lead to lower values for E_i and A_{it} and therefore make it more attractive to register a pesticide in a particular market segment. The manufacturer potentially benefits from harmonization two ways: through lower costs for the each market segment he/she serves and the possibly that it will be profitable to sell the product in additional market segments.

3. *Of course a more complicated version would consider negative impacts on other pesticides and related products — such as seed varieties -- already established by the manufacturer. The number and effectiveness of competing pesticides registered in each market segment will affect potential market size.*

Harmonization however, may only benefit the pesticide user indirectly. If there were a large number of manufacturers producing the same pesticide, competition among them would force down the price so that all the benefits from reducing annual fees would eventually go to the pesticide user. If fees were such that manufacturers enjoyed high profits in a particular market, additional manufacturers would have an incentive to obtain the rights to sell the pesticide forcing down the price to a level where fees discouraged additional market entrants. In such a market, lower registration costs should result in lower market prices of pesticides.

However, if the right to sell a particular pesticide is held by a single owner of the intellectual property rights and the pesticide has some unique advantages, the demand function will be downward sloping. There will be no incentive to change prices just because harmonization has reduced E_i and A_{it}. It is only in the long run when lower fees have resulted in the development of better substitute pesticides that the demand function will become more elastic and the benefits of harmonization will be felt at the farm level.

Furthermore, when the owner of the right to sell the pesticide is able to maintain different prices in different market segments he/she may be better off. His/her operating profits will be maximized if the marginal revenue is equal to the marginal cost in each market segment.

The same pesticide sold in both Canada and the U.S. for the same use can differ in several important respects. The pesticide may be sold at different product concentrations, which has important implications for application. In all cases, the pesticides will have label as prescribed by the regulation in each country. A pesticide can be thought of as consisting of a bundle made up of the compound itself *and the label*, which dictates the crops that the compound can be used on, the maximum allowable application rate and the conditions under which the product can be applied. Products from another country are typically not allowed to be used because their label does not reflect an identical set of the regulations. Thus in a strict sense, because the label differs from country to country, the product also differs.

Because of these differences farmers cannot import pesticides from across the border in North America even for their own use. Pesticides available on one side of the border may not be available on the other or may be available for different uses. The regulation therefore clearly prevents cross-border arbitrage and establishes market segmentation.

3.2 Pricing issues

Ongoing differences in pesticide prices between Canada and the U.S. have resulted in a number of studies to monitor price differentials and to examine the impact on producers in various countries (Taylor and Koo; Taylor and Gray; Carlson, McEwan and Deen; McEwan and Deen). The magnitude of the difference and the perceived economic impact has led to legislation being introduced in the U.S. Senate to allow farmers to import pesticides for their own use from Canada if prices are lower (Dorgan, Baucus and Conrad). While there is considerable interest in the relative prices of herbicides by farmers and politicians, there has not been a large body of research conducted to assess why pesticide prices differ.

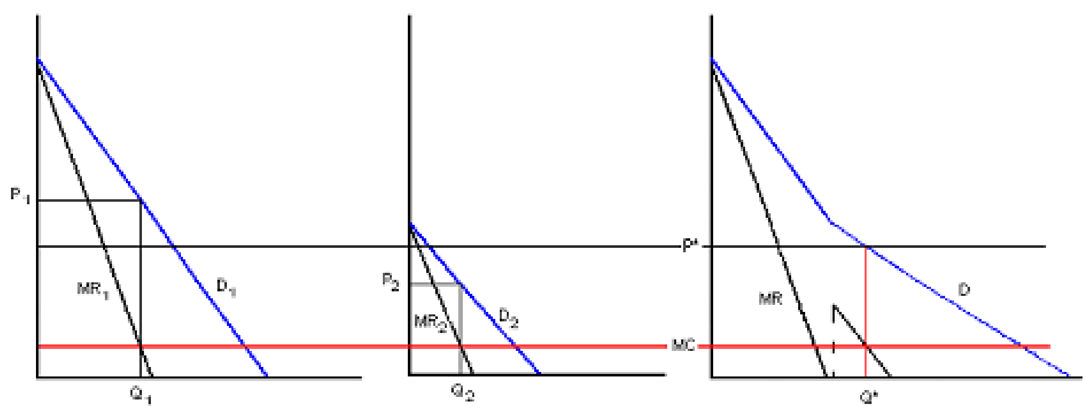
Higher prices in one market could result from real cost differences in serving the two markets, because the products sold in each market differ in some significant way or because of price discrimination. Different prices themselves do not necessarily imply price discrimination is being practiced. In simple terms price discrimination exists only if the same product, net of shipping costs and embedded taxes, is sold at different prices in two markets (Tirole, p. 133). We will return to this point in the conclusion because it is central for policy decisions about pesticide regulation.

3.3 The theory of price discrimination

Price discrimination is typically discussed in intermediate microeconomics texts as part of the development of monopoly behavior. Essentially price discrimination is profitable when the firm can identify distinct market segments which have different demand curves. By equating marginal revenue and marginal cost in each market the monopolist increases profits above the level that is achieved by simply summing the individual demand curves and using the aggregate marginal revenue curve (Figure 1). In these discussions, because price discrimination results in the transfer of more consumer surplus to producers (i.e. profits are higher under price discrimination), there is a presumption that price discrimination is undesirable.

FIGURE 1

Equilibrium under price discrimination and uniform pricing



A potentially interesting consequence of working with what is essentially a kinked demand curve is that at the kink marginal revenue becomes discontinuous. In addition, depending on the specific shapes of the demand curves, it is possible that marginal cost intersects both segments of the marginal revenue curve, as is shown in Figure 1. This provides an additional source of price indeterminacy for a profit maximizing firm. These issues are discussed in the literature on oligopoly pricing, but the consensus in that literature is that the there are no *a priori* reasons for specifying a kink at a given point on the demand curve for an oligopolist (Ferguson, p. 347; Tirole, pp. 243-244). By contrast, in the case of distinct national demands that are aggregated into a single market, the existence of a kink is almost certain and its location on the aggregate demand curve is well defined. This suggests that pricing strategy is likely to be complex over a significant range of outputs if price discrimination is eliminated.

Empirically, the monopolist requires estimates of elasticity of demand in each market and knowledge of the firm's marginal cost to establish price levels. If this information is available then the profit maximizing equilibrium condition is given by:

[3] $$MC = MR_1 = p_1\left(1-\frac{1}{\eta_1}\right) = MR_2 = p_2\left(1-\frac{1}{\eta_2}\right).$$

where *MC* is marginal cost, MR_i, p_i and n_i are marginal revenue, price, and point demand elasticity respectively in country i. This implies that a higher price will be charged in the country with the less elastic demand and the price would only be the same if by chance the demand elasticity is the same. Since elasticities depend both on the slope of the curve and a specific price quantity combination on the curve, this is an unusual event.

Discussions of price discrimination normally adopt Pigou's three part classification (Phlips, pp. 11-14). First degree price discrimination assumes that the firm has complete knowledge of each individual's demand schedule and can prevent each customer from reselling the commodity. This allows each unit to be sold at a unique price and exhausts all consumer surplus. Second degree price discrimination assumes the firm can sell units of output at different prices to customers in the same market. The firm is able to separate customers into groups and charge each group a different price that reflects the minimum value to members of that group. Third degree price discrimination exists when the firm can separate the markets for its products but has no specific information about the nature of the demand by any individual within a market segment. For the most part pesticides fall into the category of third degree discrimination. However there is the possibility for second degree discrimination to exist if prices vary by volume purchased. In practice volume discounts are less controversial than non-uniform prices for the same quantity.

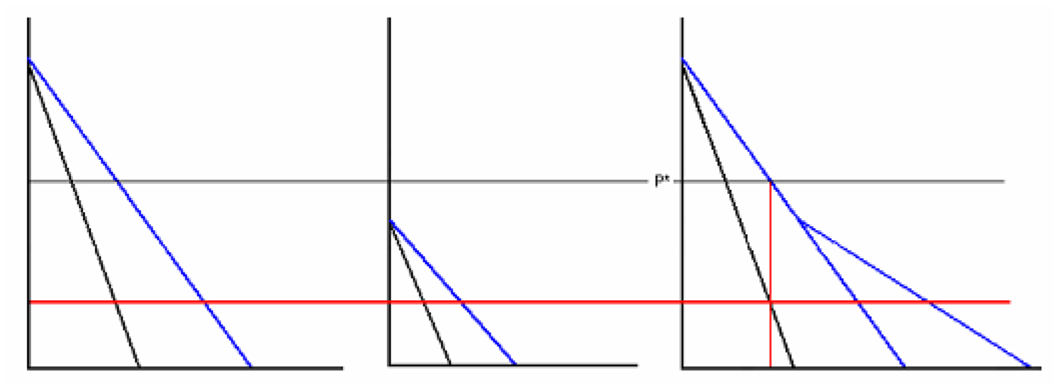
Most analysis of price discrimination employs linear demand curves. While the use of linear curves is typically a benign assumption, in the case of price discrimination it leads to some interesting anomalies. First, if both markets are served when price discrimination is not adopted, then price discrimination results in no change in aggregate output. The distribution of output is simply shifted with the more elastic demand segment receiving a lower price and larger share than under a uniform price. Second, if both markets have a common vertical intercept, such as the first unit sold in each market is sold at the same price, then price discrimination has no effect (Hadar, p. 88). In this case both the profit maximizing price and the quantity are invariant under price discrimination and under the single aggregate market.

A somewhat more sophisticated study of the effects of price discrimination has been suggested by Varian (1985). He notes that where there are significant differences in the size of the two markets it is possible that without price discrimination the smaller market will not be served. This results if the profit maximizing price in the aggregate market is above the intercept, or reservation price, in the small market (Figure 2). Higher demand in the large market with a a single and lower price is not sufficient to offset the lost sales in the small market. Varian concludes that a necessary condition for price discrimination to be welfare enhancing is that output has to be higher under price discrimination than under a single price.

Tirole concludes that the welfare effects of third degree price discrimination are ambiguous (2001, p. 139). Consumers in low elasticity of demand markets lose, but consumers in higher elasticity markets and producers benefit. Thus, even if output remains unchanged, price discrimination can be socially beneficial if the welfare gains exceed the welfare losses. Further, Tirole notes that in cases where the government is not neutral in terms of distributional issues, it is possible that the aggregate social welfare gains from discrimination are positive if low income customers have high price elasticity and high income customers have low price elasticity, so that welfare losses to the high income group are more than offset by gains by the low income group. Thus it is clear that one cannot *a priori* make a case against price discrimination on the basis of income distribution. (Tirole, 2001, pp. 139-140).

FIGURE 2

Smaller market not served with single price



3.4 Cross-border price patterns

Agriculture and Agri-Food Canada fund two studies each year that collect price data in locations close to the border (Thomson Corporation, McEwan). The Thomson study collects retail price data in Manitoba and North Dakota and Minnesota for wheat, canola and other cereal herbicides. McEwan collects similar herbicide data in Ontario, Michigan, Ohio, Illinois and Indiana for corn and soybean products. Taylor and Koo and Taylor and Gray provide a recent comparison of price differentials between North Dakota and adjoining Canadian provinces.

The prices are standardized for units and concentration of the effective ingredient, and then adjusted using the prevailing exchange rate. Carlson, McEwan and Deen report average prices for the period 1993-97 for 32 pesticides as summarized in Table 3. For eight of the 32 the difference between average prices is less than 5 percent of the average price in both countries. Prices were lower in Canada for 16 of the 32 and this was especially likely to be the case for herbicides. Prices were lower in the U.S. for eight pesticides, seven of which are “other pesticides.” In general one can conclude that some prices are systematically higher in Canada than the U.S., others are significantly lower, while others are roughly the same.

TABLE 3

Comparison of average pesticide prices in Manitoba with North Dakota/Minnesota, 1994-99

Price situation	Herbicides	Other pesticides	Total
Less expensive in Canada	11	5	16
No difference*	6	2	8
Less expensive in the U.S.	1	7	8
Total	18	14	32

* Difference is less than 5% of the average price in both regions.

Source: Gerald Carlson, John Deal, Ken McEwan and Bill Deen. “Pesticide Price Differentials Between Canada and the U.S. 1999.” p. 14.

McEwan collected price information for up to five retail outlets in eleven Canadian locations in Ontario, eleven times a year. Similar information was collected from seven U.S. locations in the

North-Central states. He performed exchange rate and unit of measure adjustments to the American data before giving it to us. We regressed deflated prices against a system of trend and dummy variables for location to determine mean and variance by location. The estimated equations are summarized in Table 4 while Figure 3 shows expected prices for three representative compounds for a specific time period in each market surveyed. Each bar in the figure shows the 95 percent confidence interval with the black horizontal bar showing the expected price.

TABLE 4

Summary of Regression Results

Variable/Statistic	Trifluralin	Glyphosate	Malathion
Range of location coefficients:			
Canada	-0.43 – 0.33 (5 of 11)	-0.35 – 0.44 (5 of 11)	-0.69 – 0.92 (9 of 11)
U.S.	-0.73 – 0.72 (6 of 7)	-0.82 – 0.80 (5 of 7)	-0.60 – 0.82 (6 of 7)
Trend in Canada	-0.016 (-10.5)	-0.017 (-9.3)	0.044 (29.7)
U.S. trend differential	-0.021 (-7.7)	-0.007 (-2.5)	-0.024 (-10.6)
Constant	12.88 (311.2)	12.66 (273.6)	7.25 (196.6)
U.S. Canada differential	0.41 (9.9)	4.45 (96.0)	-0.76 (-20.7)
R-squared adjusted	0.31	0.92	0.68
Mean dependant variable	12.13	11.27	8.23
Regression standard error	0.91	1.28	0.90

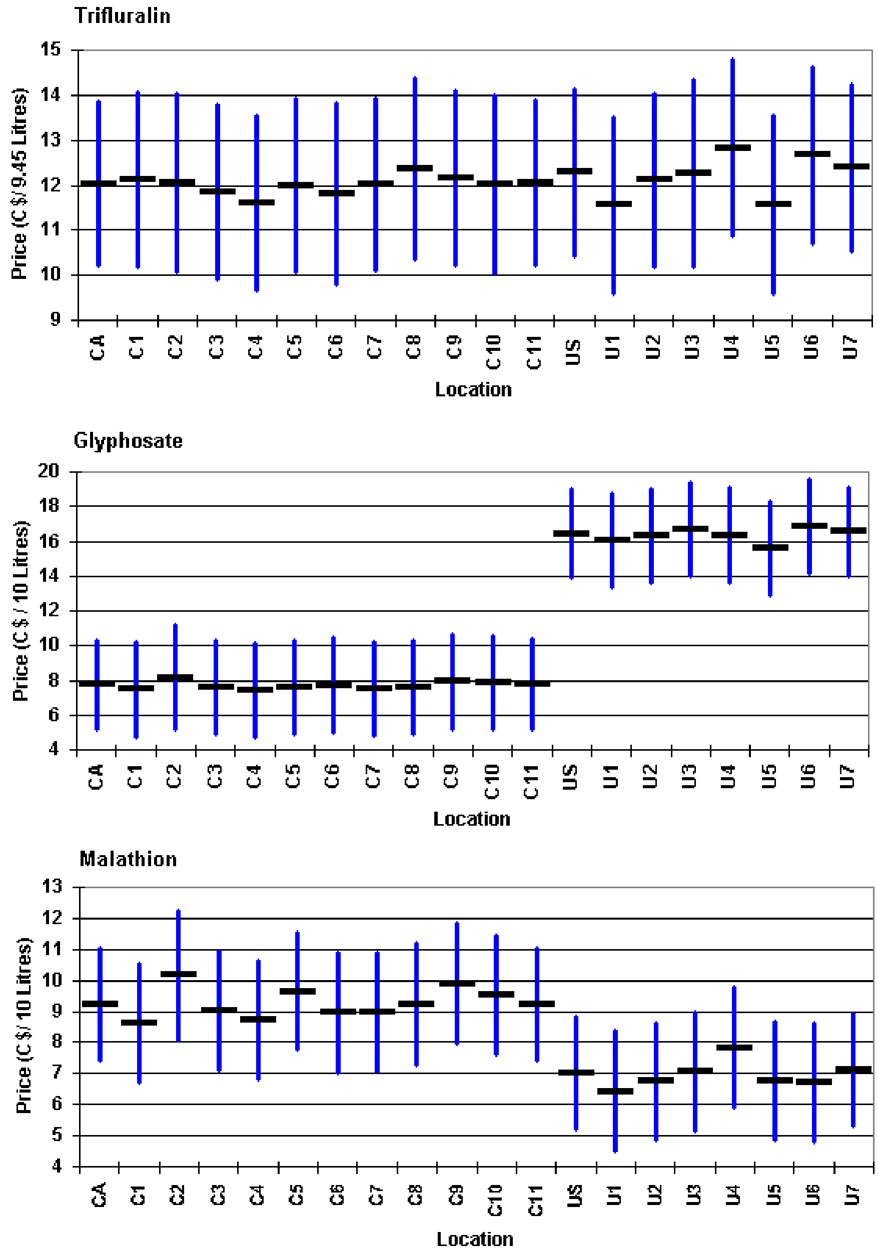
T-Statistics are reported in parentheses. For the location coefficients, the number significantly different from zero at the 95 percent confidence level is given

The top element of Figure 3, Trifluralin, shows a pattern of mean and variance that is highly homogeneous within each country and across the border. There is very little evidence of differences in retail cost structure in any of the locations for Trifluralin. The second and third elements of the figure show very different results obtained for Glyphosate and Malathion. Glyphosate is much more expensive in the U.S., while Malathion is significantly more expensive in Canada. The homogenous price pattern within each country combined with the significant difference between countries implies that we are not just seeing the effects of retail level phenomena, but rather the effects of a systematic pricing policy followed by the manufacturer, such as simple price discrimination.

Other more complicated marketing strategies could also result in the price patterns observed. Companies might be expected to recover the cost of registration in their wholesale prices and avoid cross-subsidizing registration costs in one country with revenues from another. In addition, each country provides patent protection for a defined length of time, which creates an incentive for chemical companies to attempt to recover their investment costs within the patent life so they have adequate revenue to remain in business on an ongoing basis. The registration process takes place within this patent window, and as regulators in Canada have already recognized that the process takes longer in Canada, there is a shorter period of time available to the company to recoup its costs, and hence a higher price is required. While these may be factors in pricing policy, the contrasting results for Glyphosate and Malathion suggest that demand factors are important at least for some pesticides.

FIGURE 3

95 percent confidence intervals for trifluration, glyphosate and malathion for Canadian and U.S. locations



3.5 Implications for price discrimination

Price discrimination is one explanation for cross-border price differences but there are several alternative explanations to consider. These include some combination of differences in regulatory structure, different market size, different levels of competition among products, or different retail structures.

If regulatory procedures are more onerous in one country than the other, then one would expect that price differences would be higher in the country with the more expensive regulatory structure. This explanation should lead to a pattern of prices being consistently higher on one side of the border.

Market size may be important for the following reasons. If a product is used on multiple crops, or on crops that have large acreages, then economies of scale and size in production and distribution may exist that explain price differences. Similarly, while fixed costs should not enter pricing decisions in the short run, the high costs of developing and registering a compound have to be recovered over a relatively short period if the manufacturer is to remain in the pesticide business. Consequently larger markets allow these fixed costs to be "spread" over a larger base of output. Market size effects can be roughly thought of as influencing the how far from the origin the demand curve for a product lies. However, such an explanation implies that prices would be systematically lower in the market with the greater volume of sales.

If each country had a different retail structure with different levels of mark-up or different pricing strategies this could lead to different price regimes. Differences in the relative influence of cooperatives market share, as opposed to investor-owned firms or factors that influence the level of retail competition could also play a role in explaining price differences. In this situation, prices should systematically differ being consistently higher on one side of the border or in certain markets on either side of the border.

Competition effects are the second major dimension that can explain price differences. Competition can be thought of in several ways. The first is that for some compounds multiple manufacturers make the same active ingredient. In these cases each manufacturer has very limited ability to alter prices without a significant decline in sales. Even when a product remains "on patent" so no other product has the same active ingredient there can be significant competition. Other producers may have other compounds that provide essentially the same level of crop protection, or farmers can adopt alternative control strategies such as increased cultivation. In a rough sense one can think of the degree of competition as having its largest influence on the slope of the demand curve. For products where there are limited alternative, ceteris paribus, one would expect a steeper demand curve. But as long as pesticide manufacturers face a downward sloping demand function they have the opportunity and incentive to follow monopolistic pricing strategy such as price discrimination.

There is an expectation that producers of pesticides will be able to recover fixed costs of product development and registration through charging prices above marginal cost. Patents are extended to the companies so that they can recover the research costs. Pesticide manufacturers can be expected to recover the fixed costs of product registration in the same way. Firms can only set price above marginal costs when competition is controlled and they are therefore facing a downward sloping demand function, in which case they maximize profits by setting price so that marginal revenue equals marginal cost.

Price discrimination is a simple extension of this pricing practice to segmented markets. It is a viable strategy if markets can be segmented and if the relative demand levels differ enough to make discrimination a higher profit alternative than adopting a uniform price. Pesticide regulations clearly have the effect of providing cross-border segmentation. Price discrimination is also a regular business practice—the various forms of volume discounts are a ubiquitous example. It also has a long history in Canadian agriculture with evidence of price discrimination in the farm machinery market first reported in the 1960s (Green).The only restriction on price discrimination in Canadian law circumscribes its use among purchasing competitors.[4] Canadian competition law cannot protect farmers from price discrimination among producers in different countries. In fact, it would be surprising to find that chemical companies did not also practice price discrimination wherever possible.

4. *Consumer and Corporate Affairs Canada Bureau of Competition Policy. "Price Discrimination Enforcement Guidelines", available http://strategis.ic.gc.ca/SSG/ct011403.html*

Section 4

Effect of eliminating price discrimination

In this section we estimate what would be the effects of eliminating cross-border price discrimination for pesticides. It is not clear that this is possible since it is in the pesticide manufacturers' interest to maintain segmented markets. The three national regulatory bodies — Pest Management Regulatory Agency (Canada), the Environmental Protection Agency (U.S.) and the Comisión Intersecretarial para el Control del Proceso y Uso de Plagicidas y Sustancias Tóxicas (Mexico) are currently considering establishing a single labeling system for North America. Such as system, together with the adoption of the amendment proposed by Dorgan, Baucus and Conrad to allow cross-border imports for own use, might be sufficient. But whether it is possible to fully achieve a single North American market or not, it is possible to predict what it would look like in terms of prices and the consequences of making the change for the principle participants in the pesticide markets.

4.1 Estimation of the consequences of price discrimination

The analytical model employed to show the consequences of eliminating price discrimination is based on observed quantities and prices for a specific year and on the assumption that firms engage in price discrimination. This provides information about point elasticities in each market through equation (1). The data provide sufficient information to calibrate a two parameter demand function in each market. We investigate both the linear and non-linear approaches since it is not clear, *a priori*, how much the choice of functional form will influence the modeled behavior of the pesticide manufacturer. In the non-linear models we have used a two parameter function that crosses both axes and which we call the semi-geometric.

The linear demand function results in some specific outcomes that may limit policy analysis. Notably, linear functions result in invariant total output under price discrimination or uniform pricing *if both markets are served*. In addition the elasticity of demand changes significantly with movement along the demand curve. Since price discrimination is driven by the existence of differences in demand elasticities this is important.

The semi-geometric function family allows the demand function to take a non-linear form but with the possibility of intercepts on both the price and quantity axes. Unlike linear demand curves, exponential functions result in output changes between price discrimination and uniform price behavior. Depending on the specific shapes of the two functions aggregate output can increase or decrease when moving from price discrimination to uniform prices and vice versa. This result is significant because a necessary condition for price discrimination to be welfare enhancing is that aggregate output be larger under price discrimination than under uniform pricing. More detail on the specific functions employed is available in Freshwater and Short.

Linear model

The Canadian linear demand function is:

[4] $Q_{ca} = a - bP_{ca}$

where Q_{ca} is quantity demanded, P_{ca} is price and *a* and *b* are parameters. The own price demand elasticity is

[5] $\eta_{ca} = \frac{P_{ca}}{Q_{ca}} \frac{dQ_{ca}}{dP_{ca}} = \frac{-bP_{ca}}{a - bP_{ca}}$

These two equations can be inverted and a and b solved as functions of a single observed values for quantity and price using the base period, $Q_{ca,0}$, $P_{ca,0}$, and their corresponding own price demand elasticity.

Neither demand elasticity nor marginal cost are known but we do know that marginal cost must be positive and less than the lower of the two observed prices. If a specific value for the marginal cost is chosen, then the own price elasticity can then be determined as a function of marginal cost and price, by inverting the price discrimination equilibrium equation [3] at the observed price:

[6] $\eta_{ca,0} = \frac{P_{ca,0}}{P_{ca,0} - MC}$

We therefore calibrate the model for a range of possible values for marginal cost in the interval {0, 1} as a share of price. A different own price elasticity is found for each possible value of marginal cost and each own price elasticity is used to solve equations [4] and [5] for the demand parameters. The parameters for the corresponding American demand function are found in the same way.

After the Canadian and American demands are calibrated, we find the effect of imposing arbitrage on prices and quantities in both countries by solving the system of equations consisting of the Canadian demand, the American demand and the equilibrium condition. Arbitrage implies that:

[7] $P_{us} = P_{ca}$

The changes in overall demand, rents accruing to the pesticide manufacturer and welfare of consumers in each country can then be calculated.

The non-linear model

The linear demand assumption is commonly illustrated in theoretical analysis of price discrimination but it is a special case. It is also well-known to have the somewhat anomalous result that output is invariant with the elimination of price discrimination and all that changes is the share going to each market. We therefore consider the effect of relaxing the assumption of linear demand functions.

A wide variety of functional forms could be used but we restricted ourselves initially to two parameter functions that could be calibrated using the same assumptions used for the linear demand functions. Limiting ourselves also to demand functions with intercepts on both axis further constrains the choice. The price axis intercept appears to be critical to results.[7] We ended up using the functional form in equation [8]:

[8] $Q_{ca} = (a - P_{ca})^b$

where Q_{ca} and P_{ca} are the Canadian quantity demanded and price respectively, *a* and *b* are parameters. This produces a demand equation that is convex to the origin but one that can be calibrated following a procedure similar to that used for the linear demands. The demand elasticity of equation [8] is:

[9] $\eta_{ca} = \frac{P_{ca}}{Q_{ca}} \frac{dQ_{ca}}{dP_{ca}} = \frac{-bP_{ca}}{a - P_{ca}}$

Again, the parameters *a* and *b* are found by solving equations [1] and [2] for the base period price and quantity values and a range of values for marginal cost, which as before imply specific values for own price demand elasticity. Again the process is repeated for the U.S. Unlike the linear model for which there is a simple analytical solution once marginal cost is specified, the non-linear model has to be solved by numerical methods.

4.2 Data on pesticide use

Data on pesticide pricing and quantity is not consistently collected on a national or international

7. *We also experimented with a three parameter functional form that allowed us to set the price-axis intercept parametrically. Since these results are consistent with those obtained from the two-parameter equation, only the latter are reported.*

basis. We consequently use a number of data sources that each provide a portion of the information required to calibrate the models. Consequently the possibility for data deficiencies leading to weak models should not be discounted. Price information comes from the Carlson, McEwen and Deen study for the year 1997. Price data were reported in this study with corrections for exchange rate and formulation differences. These price data are from distinct parts of the U.S. and Canada and we have no way of knowing whether they reflect prevailing prices in other regions. However, they are from regions where farmer concern with pesticide price differentials has been the greatest in recent years. Quantity information for the U.S. comes from NASS data on pesticide use and in Canada it comes from Carlson, McEwen and Deen.

Specific compounds for analysis were taken from Short and Freshwater. Then we examined price data for a number of major herbicides over a period of time and chose four herbicides for analysis in this study. They are Glyphosate, Sethoxydim, Clopyralid, and Fenoxaprop. These four compounds are chosen because they are widely used in both countries and they exhibit a spectrum of relative prices.[8]

Glyphosate, Fenoxaprop and Clopyralid have a higher price in the U.S. than Canada. Sethoxydim is cheaper in the U.S. than in Canada. The range in relative quantities applied goes from roughly three times as much Clopyralid in the U.S. as Canada to six times as much Sethoxydim. Table 5 provides the basic data for the five pesticides for 1997, with all prices expressed in $U.S. per unit of active ingredient, and quantities expressed in 1,000 lbs. of active ingredient.

TABLE 5

Herbicide price and quantity data, 1997

	CANADA		UNITED STATES	
Herbicide	**Price**	**Quantity**	**Price**	**Quantity**
Glyphosate[c]	$11.44	4,691	$18.79	21,858
Fenoxaprop[b]	$184.19	175	$284.24	950
Clopyralid[a]	$163.50	68	$228.67	187
Sethoxydim[b]	$204.29	174	$153.03	1,056

[a] Used for broad-leaf weeds.
[b] Used for grassy weeds.
[c] Used for general vegetation.
Source: authors calculations based upon data available in Carlson, McEwen and Deen and NASS.

To calibrate the model we adjust prices and quantities to normalized units where the observed Canadian price is set at 1 and the observed Canadian quantity is set at 100. Corresponding observed U.S. prices are re-specified to maintain the same relative differences. Thus, changes in the model are in multiples of the 1997 prices and quantities.

4.3 Linear results

Figure 4a shows a Canadian demand function with marginal cost assumed to be 20 percent of the observed price in Canada. The demand function is normalized with observed price set equal to 1.0 and observed quantity demanded equal to 100 at the observed price.

With marginal revenue set equal to marginal cost at this point, the demand elasticity can be calculated at 1.25. Assuming the demand function is linear gives the rest of the demand function.

Figure 4b shows both the Canadian and American demands with axis scaled to accommodate the larger American demand for one of the pesticides examined (Glyphosate). The observed American price is 1.64 relative to that in Canada

8. *Data on quantity of pesticides used are not available for Canada. We were able to make rough estimates of quantities used for a small number of major pesticides used on the most important crops grown Canada.*

while the observed American quantity is 466; these are shown in Figure 4b as point c. American demand is calibrated in the same way from marginal cost. Equating marginal revenue (not shown) with marginal cost gives a demand elasticity of 1.14 at the observed point. Assuming the American demand is linear gives the rest of the American demand function shown in figure 4b.

Maximizing profits with a common price in both markets results in a rise in the Canadian price from 1.00 to 1.46 while the U.S. price falls from 1.64 to 1.46.

Figure 4 also shows the result of eliminating price discrimination. The Canadian market adjusts to clear at point b while the American market adjusts in the opposite direction to clear at point d.

The areas A+B show welfare losses for Canadian farmers. The lightly shaded area shows gains for American farmers. It can be seen that the increase in demand by American farmers exactly offsets the fall in demand by Canadian farmers so the fall in costs of production represented by area D is exactly offset by the gain in area E and there is no change in cost for the manufacturer. (This can be shown to always be the case for linear demands.) The heavily shaded area is also exactly equal to area C + 2B so the manufacturer increases sales by 2B. However the manufacturer also loses from the lower price charged American farmers by the amount of the rectangular section of the lightly shaded area.

FIGURE 4

Effect of the elimination of price discrimination with linear demand functions

a. Canada   b. United States and Canada

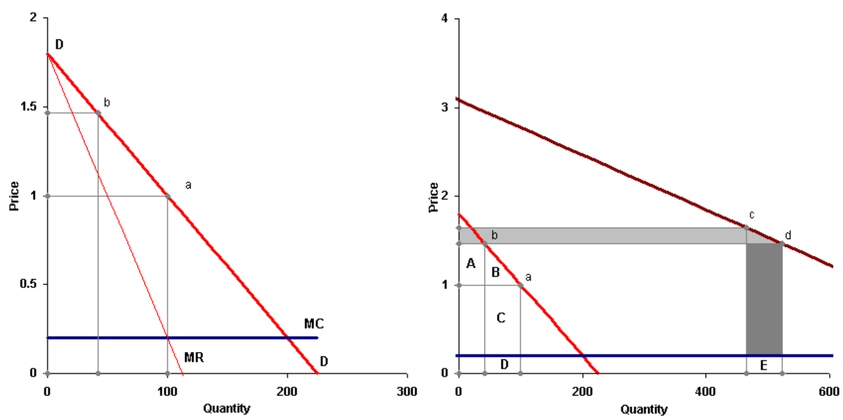
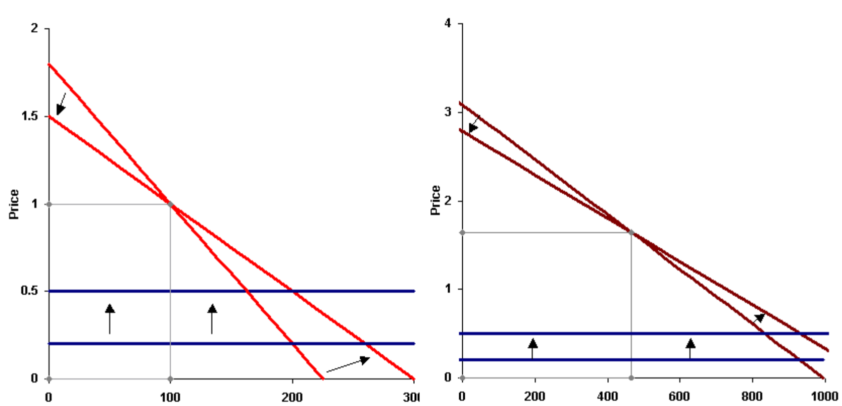


FIGURE 5

Effect of an increase in the value assumed for marginal cost

a. Canada   b. United States



As already stated, marginal cost must lie between 0 and 100 percent of the lower price in the two markets. Figure 4 assumes a value near the lower point of this range. Figure 5 shows what happens when a higher value for marginal cost is assumed. A higher marginal cost results in a higher demand elasticity at the observed point, which implies the entire Canadian demand function rotates in a counterclockwise direction as shown in Figure 5a. The American demand function is also more elastic with a higher assumed value of marginal cost so it too rotates in a counterclockwise direction at its observed point as shown in Figure 5b (the axis in Figure 5 is scaled for the larger American demand.)

FIGURE 6

Comparison of the effect of the elimination of price

a. Canada   b. United States

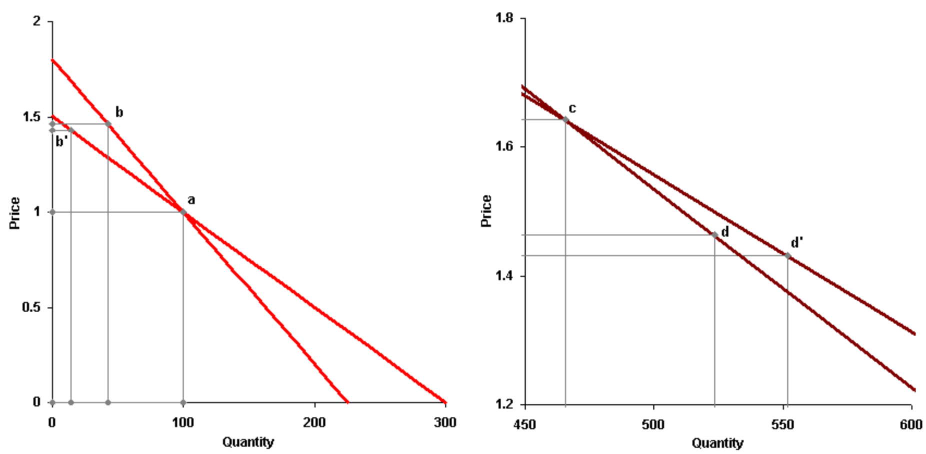


Figure 6 shows what this implies for the optimal monopoly solution without price discrimination at point b'. The price in Canada now increases 43 percent to 1.43, almost identical but actually slightly less than it did when marginal costs were 20 percent of price. There is an even larger reduction in Canadian demand but a smaller loss in welfare for Canadian farmers because of the more elastic demand function.

Figure 6b shows that the opposite is happening for American farmers. They benefit from a slightly larger reduction in price. Their welfare increase is larger because of the increase in commodity demanded and the more elastic demand function.

Results are presented in detail for the four pesticides analyzed in the Annex but impacts on prices and quantities are summarized in Table 6. The common price that results from the elimination of price discrimination is always much closer to the base U.S. price because the U.S. market is so much larger. This point is important in the context of the political debate over price differentials. While it may be possible for Canadian farmers to see significant price changes in those compounds where Canadian prices are higher if uniform pricing is imposed, this will not be the case for U.S. producers. High prices in the U.S. will not fall by much, so the main benefit that U.S. producers would obtain under uniform prices would be a more level playing field relative to Canadian farmers. Most importantly farmers seem to be under the impression that prices will harmonize at the lower price. Clearly the logic of price arbitrage is that prices equilibrate between the two starting points, not at the lower one.

The change in quantities demanded is larger than the change in prices because all demands are elastic. The demand changes are much larger in Canada in relative terms, because of the larger changes in prices. Except for Sethoxydim, Canadian demand elasticities are larger, which contributes to the relatively larger changes in Canadian demand.

TABLE 6

Linear model results for prices, quantities, consumer surplus (CS) and processor profits (percent change from base)

Marginal cost	Canadian		American		Total quantity	Canadian CS	American CS	Pesticide profits	Total welfare
	Price	Quantity	Price	Quantity					
Glyphosate									
20	46	-11	-58	12	0	-82	26	-5	2
30	45	-11	-65	14	0	-88	30	-6	2
40	44	-12	-74	16	0	-93	34	-7	2
50	43	-13	-86	19	0	-98	40	-10	3
60	64	0	0	0	-18	-100	0	-8	-8
70	64	0	0	0	-18	-100	0	-6	-6
80	64	0	0	0	-18	-100	0	-5	-5
Fenoxaprop									
20	41	-8	-52	10	0	-77	20	-3	1
30	41	-9	-58	11	0	-83	23	-4	1
40	40	-9	-67	12	0	-89	26	-5	2
50	39	-10	-78	14	0	-95	31	-7	2
60	38	-11	-95	17	0	-100	38	-9	3
70	54	0	0	0	-16	-100	0	-6	-6
80	54	0	0	0	-16	-100	0	-5	-5
Clopyralid									
20	26	-10	-32	12	0	-54	25	-3	1
30	25	-10	-36	13	0	-59	28	-4	1
40	25	-11	-41	15	0	-66	32	-5	2
50	24	-11	-48	17	0	-73	38	-6	2
60	23	-12	-58	21	0	-82	46	-9	3
70	22	-13	-72	26	0	-92	59	-13	4
80	19	-15	-96	35	0	-100	81	-21	7
Sethoxydim									
20	-22	3	26	-4	0	60	-9	-9	1
30	-23	3	29	-5	0	67	-9	-9	1
40	-23	3	32	-5	0	75	-10	-10	1
50	-23	3	37	-6	0	86	-12	-12	1
60	-23	3	42	-7	0	101	-13	-13	2
70	-23	2	49	-8	0	122	-15	-15	3
80	-24	2	59	-10	0	153	-18	-18	6

For two of the products, the increase in price is sufficient to eliminate all Canadian demand for some levels of marginal cost. This happens with a marginal cost around 60 percent of the price for Glyphosate and 70 percent of the price for Fenoxaprop. In these cases the result is a drop in total demand by the amount of Canadian demand and no change in American price and quantity demanded.

Table 6 also shows the welfare changes that result from elimination of price discrimination for the four pesticides. There are very large impacts on Canadian farmers by eliminating 50-100 percent of consumer surplus in all cases where the Canadian price is lower than the American price with price discrimination although Canadian farmers show a huge increase in consumer surplus for Sethoxydim. As one would expect, the effect on American farmers is large though not nearly as large as it is for Canadian farmers.

The effect on pesticide profits is generally much smaller in relative terms being 10 percent or less of base level profits in all but four of the cases evaluated. This is important because it suggests that eliminating price discrimination would have only a small impact on product availability.

As the assumed value for marginal cost increases, the losses from the elimination of price discrimination increase for the manufacturer and Canadian farmers but increase for American farmers (see Table 6). Total welfare gains from the elimination of price discrimination are sum of pesticide profits and American farmers. Total welfare changes are small relative to the transfers involved but they are positive and increasing with assumed values for marginal cost.

The overall effect of eliminating price discrimination is positive in all cases except when Canadian farmers are priced out of the market. Sales in the American market continue under the same prices as would prevail with price discrimination. Eliminating price discrimination in this case therefore results in losses for Canadian farmers and in pesticide profits and no gains for American farmers. So eliminating price discrimination reduces both pesticide output and total welfare consistently with Varian's conclusion. The size of these losses continues to be dependant on the value assumed for marginal cost.

As the assumed level of marginal cost increases, we draw the following general conclusions:

- Elasticity in both markets increases as the demand curves rotate in a counter clockwise manner to decrease the slope and intercept to preserve equation [3], but the U.S. elasticity increases at a faster rate.
- Compared to the initial price change caused by moving to a uniform price, there is little effect on price with increases in marginal cost.
- The level of profit falls, while the aggregate level of social welfare increases but at a slower rate. Because increased herbicide expenditures account for a larger part of the area under the demand curve, there is a reduction in consumer surplus even as the rotation of the demand function tends to increase the total area under the curve.
- Where aggregate welfare gains exist there is the possibility that winners, such as the farmers whose price falls, could compensate the losers and still come out ahead.
- Markets where there are larger differences in the relative quantities sold experience larger absolute changes in social welfare and profit than is the case where markets are of similar size, even though the net change in social welfare is similar.

4.4 Non-linear results

In this section we evaluate the importance of the functional form assumed for the demand functions. The effect on the solution of repeating the analysis with equation [8] is illustrated in Figure 7 points b" and d" while b and d reproduce the linear solution from Figure 4. In terms of evaluating the effects of the elimination of price discrimination, the effect assuming a non-linear demand is exactly the opposite of assuming a higher value for marginal cost.

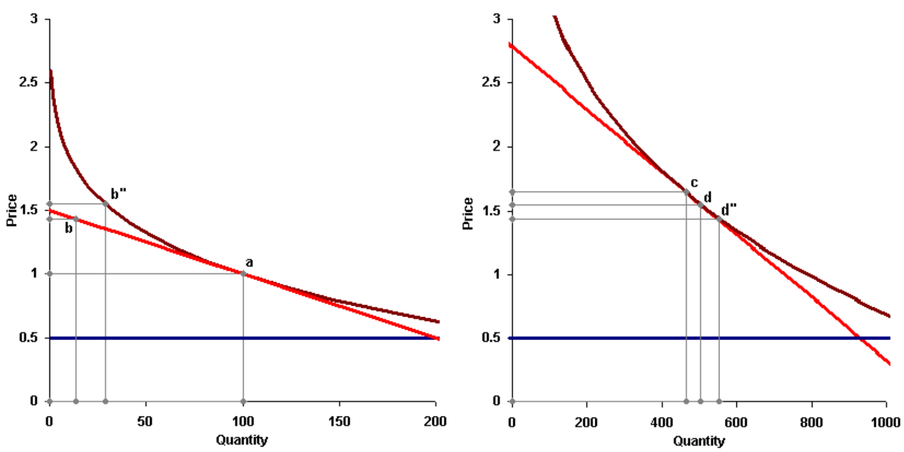
The part of the Canadian demand function critical to the solution is rotated clockwise while the critical section of the American demand function is rotated in a counterclockwise direction. The non-linear solution results in a slightly higher equilibrium price than the corresponding linear solution but a smaller reduction in demand in Canada. There is also a smaller increase in demand in the U.S. It should also be evident that the welfare decrease in Canada is larger in absolute terms but smaller in relative terms. The welfare increase in the U.S. is smaller in both absolute and relative terms for the non-linear demand function.

The functional form used makes absolutely no difference to who are the winners and losers from eliminating price discrimination. It also appears to make very little difference to the final price, which is always very close to the price with price discrimination in the U.S. It makes some difference to the final quantities and measures of welfare but these remain on the same general order of magnitude.

FIGURE 7

Comparison of the effect of the elimination of price discrimination with linear and non-linear demand functions

a. Canada   b. United States and Canada



There are, however, some interesting differences between the linear and non-linear solutions. The higher implicit intercept means there is very little likelihood of sales in the lower priced market being reduced to zero. Under all assumptions about marginal cost, both markets continue to be served (see Table 7). This clearly reflects the fact that the non-linear curves always lie above the linear curves and the gap increases near the origin. While it is possible that given a low enough price intercept a market the lower price market may not be served in the non-linear model, this is a far less likely situation than if linear demand curves are employed.

Another feature of the non-linear model is that it does not the give the anomalous result that aggregate demand is unchanged. Instead, we find with this functional form, that aggregate demand is invariably lower with the elimination of price discrimination. We also find – for Glyphosate, Fenoxaprop, and Clopyralid – that a reduction in aggregate demand is always associated with a reduction in aggregate welfare, which is consistent with Varian's conclusion. Note that this result for aggregate welfare contradicts that obtained for the linear model.

Interestingly in the case of Sethoxydim, the only product where observed prices are higher in Canada, uniform pricing leads to a relatively big increase in Canadian price. This reduces welfare in Canada sufficiently to offset the smaller decrease in price in the U.S. and the small loss in profit associated with uniform pricing. Consequently Sethoxydim emerges as evidence that it is possible for price discrimination to increase output and still lead to a decline in aggregate welfare.[7] It is also the only case where eliminating price discrimination is unambiguously welfare enhancing.

7. *This result would seem to indicate that Varian's conclusion is a sufficient but not a necessary condition for price discrimination to lead to an increase in total welfare.*

TABLE 7

Non-linear model results for prices, quantities, consumer surplus (CS) and processor profits (percent change)

Marginal cost		Canadian		American		Total quantity	Canadian CS	American CS	Pesticide profits	Total welfare
		Price	Quantity	Price	Quantity					
Glyphosate										
	20	53	-52	-7	8	-3	-60	10	-2	0
	30	54	-57	-7	8	-3	-65	10	-3	0
	40	54	-63	-6	8	-4	-71	11	-3	-1
	50	55	-71	-6	8	-6	-78	10	-4	-1
	60	57	-80	-5	7	-8	-85	9	-4	-2
	70	59	-90	-3	5	-12	-93	7	-5	-3
	80	63	-98	-1	2	-16	-99	2	-4	-4
Fenoxaprop										
	20	46	-46	-5	6	-2	-54	8	-2	0
	30	46	-51	-5	7	-2	-59	9	-2	0
	40	46	-57	-5	7	-3	-64	9	-2	0
	50	47	-65	-5	7	-4	-71	9	-3	-1
	60	48	-74	-4	7	-6	-80	8	-3	-1
	70	50	-85	-3	6	-9	-89	7	-4	-2
	80	52	-96	-1	3	-12	-97	3	-4	-3
Clopyralid										
	20	29	-32	-8	9	-1	-38	12	-2	0
	30	29	-35	-8	10	-2	-42	13	-2	0
	40	29	-40	-8	11	-3	-47	14	-3	0
	50	30	-47	-7	12	-4	-53	15	-3	0
	60	30	-55	-7	13	-5	-61	16	-4	-1
	70	31	-68	-6	13	-8	-73	16	-5	-1
	80	34	-85	-4	10	-15	-88	13	-7	-3
Sethoxydim										
	20	-22	28	4	-5	-1	38	-7	-1	0
	30	-22	31	4	-6	-1	41	-7	-1	0
	40	-22	35	4	-7	-1	46	-8	-2	0
	50	-22	40	4	-8	-1	52	-10	-2	0
	60	-22	46	4	-10	-2	61	-11	-4	1
	70	-22	56	4	-12	-3	72	-14	-6	1
	80	-22	70	4	-17	-4	89	-18	-13	3

As in the linear models, increases in marginal cost are associated with increases in elasticity of demand and lower profits under price discrimination. With a uniform price, higher marginal costs generally lead to lower levels of aggregate output, higher prices, lower profit and lower levels of welfare. Sethoxydim is somewhat of a counter example to these general tendencies. For Sethoxydim, output falls very slowly, price remains constant and profit declines by a small amount. Results for Sethoxydim largely reflect the fact that the large market has the lower price under price discrimination.

4.5 Conclusion

Irrespective of the choice of marginal cost and demand functions, elimination of price discrimination always results in a price in between the prices observed with price discrimination but close to the price observed in the larger U.S. market. The profits earned by the pesticide manufacturer always decline. The impact on farmers is also nearly invariant with respect to choice of functional form and level of marginal cost. American farmers benefit from the elimination of price discrimination for those pesticides with significantly higher prices in Canada while Canadian farmers lose, but typically not by a comparable amount because of differences in the underlying demand curves. The sole exception to this pattern is in the case where it is no longer profitable to supply farmers in the lower price market, in which case there is only a loss for those farmers and the pesticide company but no gain for farmers in the high price region.

The choice of a demand model for the analysis is the single most important decision in dictating the outcome for aggregate welfare. However, the type of demand function that can reasonably be estimated in this case is constrained by the limited information we have on pesticide prices and quantities sold in each country.

The case of pesticides provides a clear cut example of how borders can be used to maintain segmented markets even with free trade. The same type of analysis is likely applicable to a wide range of products where regulations, trademarks or brand names lead to downward sloping demand functions. The case of pesticides illustrates how the benefits of freer trade and regulatory harmonization for these products may be distributed.

- Clearly, free trade is not always sufficient to create a single market for products like pesticides. It will always be in the producer's interest to maintain market segmentation and price products according to differences in demand elasticities. Segmented markets for these commodities are likely to persist unless consumers have the right to import freely from other countries in the free trade area.
- Many of the benefits of regulatory harmonization should reduce compliance costs and other fixed costs. The benefits of these changes are likely to be captured by the manufacturer at least in the short run. The benefit to the consumer will be in the form of a wider range of suitable products available in the market. Consumer benefits will be realized only when greater competition from a wider range of products results in more elastic demand functions for each product.

At the most general level the implications of the analysis for pesticide policy are significant. It suggests that the social welfare implications of change are complex both in terms of short term static effects on different groups and of the longer term dynamics of the industry. There has always been a recognition that harmonization of pesticide regulation may not be desirable. The main argument in the past has been that there may be sound environmental and public policy differences that require the markets be treated as distinct entities. Our work confirms that domestic policy interests can provide an additional reason for maintaining distinct markets if one party is a net loser. We also raise the possibility that price discrimination may provide a higher level of aggregate welfare than is the case if prices are set at a uniform level.

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ANNEX

TABLE A1

Linear model calibration results

	Units	Scenario 1	2	3	4	5	6	7
MC	%	20	30	40	50	60	70	80
Glyphosate								
MC	US$	1.79	2.69	3.58	4.48	5.38	6.27	7.17
D. elasticty1		1.25	1.43	1.67	2.00	2.50	3.33	5.00
D. elasticty2		1.14	1.22	1.32	1.44	1.58	1.74	1.95
Welfare1	1000 US$	21,485	18,799	16,114	13,428	10,742	8,057	5,371
Welfare2	1000 US$	180,294	167,792	155,289	142,786	130,283	117,780	105,278
Profit	1000 US$	403,558	373,182	342,805	312,428	282,051	251,675	221,298
Welfare	1000 US$	605,338	559,773	514,207	468,642	423,077	377,512	331,947
Fenoxaprop								
MC	US$	7.46	11.18	14.91	18.64	22.37	26.10	29.82
D. elasticty1		1.25	1.43	1.67	2.00	2.50	3.33	5.00
D. elasticty2		1.15	1.24	1.35	1.48	1.64	1.83	2.08
Welfare1	1000 US$	12,903	11,290	9,677	8,064	6,451	4,839	3,226
Welfare2	1000 US$	117,518	108,769	100,020	91,271	82,522	73,773	65,024
Profit	1000 US$	260,841	240,117	219,393	198,670	177,946	157,222	136,498
Welfare	1000 US$	391,261	360,176	329,090	298,004	266,919	235,833	204,748
Clopyralid								
MC	US$	25.90	38.85	51.80	64.75	77.69	90.64	103.59
D. elasticty1		1.25	1.43	1.67	2.00	2.50	3.33	5.00
D. elasticty2		1.17	1.27	1.40	1.56	1.75	2.00	2.34
Welfare1	1000 US$	4,422	3,869	3,316	2,764	2,211	1,658	1,105
Welfare2	1000 US$	18,323	16,794	15,266	13,737	12,208	10,680	9,151
Profit	1000 US$	45,489	41,327	37,164	33,001	28,838	24,675	20,512
Welfare	1000 US$	68,234	61,990	55,746	49,501	43,257	37,013	30,769
Sethoxydim								
MC	US$	35.15	52.72	70.30	87.87	105.45	123.02	140.59
D. elasticty1		1.18	1.29	1.43	1.60	1.82	2.10	2.50
D. elasticty2		1.25	1.43	1.67	2.00	2.50	3.33	5.00
Welfare1	1000 US$	15,110	13,778	12,447	11,116	9,785	8,453	7,122
Welfare2	1000 US$	64,664	56,581	48,498	40,415	32,332	24,249	16,166
Profit	1000 US$	153,520	131,678	109,837	87,995	66,154	44,312	22,470
Welfare	1000 US$	233,293	202,038	170,782	139,526	108,270	77,014	45,759

Note: MC = marginal cost
1 = Canada
2 = United States

TABLE A2

Linear model elimination of price discrimination results

	Units	Scenario 1	2	3	4	5	6	7
Glyphosate								
MC	US$	1.79	2.69	3.58	4.48	5.38	6.27	7.17
Price1	US$	13.11	13.03	12.94	12.82	14.71	14.71	14.71
Price2	US$	13.11	13.03	12.94	12.82	14.71	14.71	14.71
Quantity1	1000 Units	2,527	2,100	1,554	831	0	0	0
Quantity2	1000 Units	31,376	31,802	32,348	33,072	27,908	27,908	27,908
Quantity	1000 Units	33,903	33,903	33,903	33,903	27,908	27,908	27,908
Welfare1	1000 US$	3,816	2,307	1,083	258	0	0	0
Welfare2	1000 US$	227,890	217,889	208,634	200,516	130,283	117,780	105,278
Profit	1000 US$	383,607	350,778	317,262	282,721	260,567	235,561	210,555
Welfare	1000 US$	615,313	570,974	526,979	483,496	390,850	353,341	315,833
Fenoxaprop								
MC	US$	7.46	11.18	14.91	18.64	22.37	26.10	29.82
Price1	US$	52.74	52.54	52.27	51.91	51.40	57.53	57.53
Price2	US$	52.74	52.54	52.27	51.91	51.40	57.53	57.53
Quantity1	1000 Units	417	359	286	186	46	0	0
Quantity2	1000 Units	5,142	5,200	5,273	5,373	5,513	4,694	4,694
Quantity	1000 Units	5,559	5,559	5,559	5,559	5,559	4,694	4,694
Welfare1	1000 US$	2,991	1,948	1,054	374	18	0	0
Welfare2	1000 US$	141,058	133,476	126,253	119,584	113,833	73,773	65,024
Profit	1000 US$	251,755	229,873	207,653	184,921	161,360	147,545	130,047
Welfare	1000 US$	395,804	365,298	334,960	304,879	275,212	221,318	195,071
Clopyralid								
MC	US$	25.90	38.85	51.80	64.75	77.69	90.64	103.59
Price1	US$	162.97	162.42	161.71	160.78	159.47	157.51	154.28
Price2	US$	162.97	162.42	161.71	160.78	159.47	157.51	154.28
Quantity1	1000 Units	58	54	50	44	36	24	4
Quantity2	1000 Units	264	267	272	277	286	298	318
Quantity	1000 Units	321	321	321	321	321	321	321
Welfare1	1000 US$	2,025	1,568	1,136	738	392	129	2
Welfare2	1000 US$	22,855	21,496	20,187	18,956	17,852	16,976	16,581
Profit	1000 US$	44,065	39,726	35,336	30,872	26,288	21,497	16,295
Welfare	1000 US	68,946	62,790	56,659	50,566	44,532	38,602	32,878

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TABLE A2 (CONTINUED)

Linear model elimination of price discrimination results

		Scenario						
	Units	1	2	3	4	5	6	7
Sethoxydim								
MC	US$	40.45	60.68	80.90	101.13	121.35	141.58	161.80
Price1	US$	156.78	156.58	156.35	156.05	155.67	155.16	154.44
Price2	US$	156.78	156.58	156.35	156.05	155.67	155.16	154.44
Quantity1	1000 Units	222	227	233	240	249	262	279
Quantity2	1000 Units	1,021	1,016	1,010	1,003	994	981	963
Quantity	1000 Units	1,243	1,243	1,243	1,243	1,243	1,243	1,243
Welfare1	1000 US$	24,158	22,972	21,821	20,717	19,682	18,754	18,002
Welfare2	1000 US$	59,154	51,283	43,459	35,700	28,031	20,497	13,178
Profit	1000 US$	151,161	129,081	106,947	84,738	62,423	39,946	17,209
Welfare	1000 US$	234,473	203,336	172,227	141,154	110,136	79,197	48,389

Note: MC = marginal cost
1 = Canada
2 = United States

TABLE A3

Non-linear model calibration results

	Units	Scenario 1	2	3	4	5	6	7
MC	%	20	30	40	50	60	70	80
Glyphosate								
MC	US$	1.79	2.69	3.58	4.48	5.38	6.27	7.17
D. elasticty1		1.25	1.43	1.67	2.00	2.50	3.33	5.00
D. elasticty2		1.14	1.22	1.32	1.44	1.58	1.74	1.95
Welfare1	1000 US$	34,338	30,418	26,439	22,389	18,254	14,009	9,619
Welfare2	1000 US$	283,548	265,404	247,144	228,758	210,234	191,557	172,710
Profit	1000 US$	403,558	373,182	342,805	312,428	282,051	251,675	221,298
Welfare	1000 US$	721,445	669,004	616,389	563,576	510,539	457,241	403,627
Fenoxaprop								
MC	US$	7.46	11.18	14.91	18.64	22.37	26.10	29.82
D. elasticty1		1.25	1.43	1.67	2.00	2.50	3.33	5.00
D. elasticty2		1.15	1.24	1.35	1.48	1.64	1.83	2.08
Welfare1	1000 US$	20,622	18,268	15,878	13,446	10,962	8,413	5,777
Welfare2	1000 US$	186,461	173,624	160,701	147,683	134,559	121,318	107,944
Profit	1000 US$	260,841	240,117	219,393	198,670	177,946	157,222	136,498
Welfare	1000 US$	467,923	432,009	395,973	359,798	323,467	286,953	250,219
Clopyralid								
MC	US$	25.90	38.85	51.80	64.75	77.69	90.64	103.59
D. elasticty1		1.25	1.43	1.67	2.00	2.50	3.33	5.00
D. elasticty2		1.17	1.27	1.40	1.56	1.75	2.00	2.34
Welfare1	1000 US$	7,067	6,260	5,441	4,608	3,757	2,883	1,980
Welfare2	1000 US$	28,922	26,704	24,467	22,210	19,929	17,622	15,285
Profit	1000 US$	45,489	41,327	37,164	33,001	28,838	24,675	20,512
Welfare	1000 US$	81,479	74,291	67,072	59,818	52,524	45,181	37,777
Sethoxydim								
MC	US$	35.15	52.72	70.30	87.87	105.45	123.02	140.59
D. elasticty1		1.18	1.29	1.43	1.60	1.82	2.10	2.50
D. elasticty2		1.25	1.43	1.67	2.00	2.50	3.33	5.00
Welfare1	1000 US$	23,360	21,492	19,604	17,695	15,761	13,800	11,805
Welfare2	1000 US$	106,948	94,501	81,906	69,136	56,156	42,910	29,307
Profit	1000 US$	153,520	131,678	109,837	87,995	66,154	44,312	22,470
Welfare	1000 US$	283,828	247,671	211,347	174,827	138,071	101,022	63,583

Note: MC = marginal cost
1 = Canada
2 = United States

TABLE A4

Non-linear model elimination of price discrimination results

		Scenario						
	Units	1	2	3	4	5	6	7
Glyphosate								
MC	US$	1.79	2.69	3.58	4.48	5.38	6.27	7.17
Price1	US$	13.72	13.76	13.81	13.90	14.05	14.27	14.57
Price2	US$	13.72	13.76	13.81	13.90	14.05	14.27	14.57
Quantity1	1000 Units	2,900	2,579	2,192	1,724	1,170	574	122
Quantity2	1000 Units	30,119	30,194	30,231	30,184	29,957	29,389	28,455
Quantity	1000 Units	33,020	32,774	32,424	31,909	31,127	29,963	28,578
Welfare1	1000 US$	13,842	10,726	7,758	5,023	2,667	944	124
Welfare2	1000 US$	312,425	293,187	273,271	252,282	229,535	204,131	176,849
Profit	1000 US$	393,762	362,736	331,679	300,657	269,853	239,754	211,410
Welfare	1000 US$	720,028	666,650	612,709	557,962	502,056	444,829	388,384
Fenoxaprop								
MC	US$	7.46	11.18	14.91	18.64	22.37	26.10	29.82
Price1	US$	54.38	54.47	54.61	54.83	55.19	55.81	56.76
Price2	US$	54.38	54.47	54.61	54.83	55.19	55.81	56.76
Quantity1	1000 Units	466	423	370	305	224	129	38
Quantity2	1000 Units	4,996	5,011	5,023	5,028	5,014	4,957	4,826
Quantity	1000 Units	5,462	5,434	5,394	5,333	5,238	5,085	4,864
Welfare1	1000 US$	9,505	7,539	5,640	3,848	2,236	941	178
Welfare2	1000 US$	201,747	188,468	174,874	160,790	145,896	129,634	111,615
Profit	1000 US$	256,290	235,227	214,130	193,013	171,939	151,093	131,017
Welfare	1000 US$	467,541	431,234	394,643	357,650	320,071	281,668	242,810
Clopyralid								
MC								
Price1	US$	25.90	38.85	51.80	64.75	77.69	90.64	103.59
Price2	US$	166.97	167.12	167.35	167.74	168.44	169.89	173.39
Quantity1	US$	166.97	167.12	167.35	167.74	168.44	169.89	173.39
Quantity2	1000 Units	58	55	51	46	38	28	13
Quantity	1000 Units	258	260	262	264	266	267	261
Welfare1	1000 Units	317	315	313	310	305	294	273
Welfare2	1000 US$	4,396	3,648	2,903	2,168	1,453	785	240
Profit	1000 US$	32,414	30,172	27,891	25,552	23,107	20,439	17,201
Welfare	1000 US$	44,686	40,448	36,196	31,925	27,634	23,330	19,088
	1000 US$	81,496	74,268	66,991	59,645	52,195	44,555	36,529

TABLE A4 (CONTINUED)

Non-linear model elimination of price discrimination results

		Scenario						
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Sethoxydim								
MC	US$	40.45	60.68	80.90	101.13	121.35	141.58	161.80
Price1	US$	158.29	158.21	158.11	157.97	157.77	157.47	156.96
Price2	US$	158.29	158.21	158.11	157.97	157.77	157.47	156.96
Quantity1	1000 Units	225	230	237	246	257	274	298
Quantity2	1000 Units	1,009	1,001	992	979	961	935	890
Quantity	1000 Units	1,233	1,232	1,229	1,225	1,219	1,208	1,188
Welfare1	1000 US$	32,134	30,394	28,666	26,963	25,306	23,736	22,345
Welfare2	1000 US$	99,899	87,562	75,106	62,522	49,800	36,940	23,977
Profit	1000 US$	151,890	129,909	107,900	85,856	63,767	41,624	19,438
Welfare	1000 US$	283,923	247,864	211,673	175,342	138,873	102,299	65,760

Note: MC = marginal cost
1 = Canada
2 = United States