# The Cost of a Licensing System Regulation: An Example from Canadian Prairie Agriculture

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Agricultural legislation and the resultant regulation that usually ensues can often change, redirect, or even stop the adoption of yield-increasing technologies that have the potential to generate substantial economic rents. This paper offers an example from the Canadian wheat sector of how a variety-licensing regulation had totally stopped the adoption of a yield-increasing technology that had the potential to increase the economic rents flowing to western Canadian farmers by 15–25 percent. This regulation further prevented high internal rates of return (greater than 50 percent) from being generated by research into this new technology.

## I. Introduction

The world wheat market, in which Canada is a major participant, is made up of many different qualities and classes of wheat. Broadly speaking, these can be divided into hard (H), medium-hard (M), soft (S), and durum (D) wheats.[1] Traditionally, western Canada (i.e., the

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[1] Generally speaking, the softer the wheat, the higher the yield, provided that moisture and the growing season are not limiting. For every 10–15 percent increase in yield, the protein content drops by 1 percent. Generally, the higher the protein content, the

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TABLE 1

PROFILE OF TOTAL CANADIAN WHEAT EXPORTS (Averages of Periods)

| Period | H Class | M Class | S Class | D Class | Total |
|---|---|---|---|---|---|
| | Canadian Exports (Thousands of Metric Tons) | | | | |
| 1957–64 | 8,086 | 0 | 213 | 603 | 8,902 |
| 1965–73 | 10,431 | 1 | 128 | 987 | 11,547 |
| 1974–81 | 10,498 | 345 | 1,267 | 1,801 | 13,911 |
| | World Trade (Thousands of Metric Tons) | | | | |
| 1957–64 | 8,834 | 15,924 | 5,977 | 1,008 | 31,743 |
| 1965–73 | 13,678 | 20,790 | 7,679 | 2,532 | 44,679 |
| 1974–81 | 14,992 | 29,779 | 17,082 | 3,585 | 65,438 |
| | Canadian Market Shares (%) | | | | |
| 1957–64 | 91.3 | .0 | 3.0 | 67.1 | 28.5 |
| 1965–73 | 76.4 | .0 | 1.7 | 36.7 | 25.8 |
| 1974–81 | 69.8 | 1.2 | 7.5 | 50.2 | 21.3 |

SOURCE.—Henning and Martin (1983).
NOTE.—The H class includes all no. 1, no. 2, and no. 3 Canadian Western Red Spring wheat from Canada and all Hard Red Spring wheat from the United States. The M class includes all no. 1 and no. 2 Canadian Utility wheat from Canada, Hard Red Winter wheat from the United States, and all exports from Australia and Argentina. The S Class includes all Canadian Western Red Winter wheat, no. 3 Canadian Utility and Eastern wheat from Canada, all soft wheat exports from France, and Soft Red Winter and white wheat from the United States. The D class is all durum wheat.

Prairies), where wheat production is concentrated, has produced and exported primarily H wheat used mainly in the production of loaf-type breads and D wheat used mainly in the production of pasta products. Historically, Canada has enjoyed between 60 and 80 percent of the world trade in H wheats and 40–60 percent of the world trade in D wheat. However, its market share of the S and M wheats has been small (table 1).

The production and exportation of Canadian wheat are regulated by a comprehensive grading system and variety-licensing regulations. The Canadian Wheat Board (CWB) was established under statutory authority to be the sole exporter of Canadian wheat, barley, and oats. The Canadian Grain Commission (CGC) was set up with statutory authority to supervise and regulate most facets of the Canadian grain handling, transport, and processing system beyond the farm gate. The Canadian Seeds Act was established, also with statutory author-

higher the unit price (i.e., the "protein premium"). Thus the Prairies, with their low rainfall and short growing season, produce a high-protein, H, low-yielding wheat. On the other hand, France, with a relatively high rainfall and a long growing season, produces a low-protein, S, high-yielding wheat. The average protein content of the American H winter wheat crop is probably the biggest single factor determining the protein premium millers are willing to pay in a given year. This is because it is the single biggest class of wheat entering the world wheat trade.

ity, as a way of ensuring that only those varieties that (1) were of acceptable quality, (2) fit into the grain grading system, and (3) showed agronomic merit would be licensed. If a variety is not licensed, it cannot be legally sold by the CWB on the export market for anything other than animal feed.

The combination of an elaborate and strict grading and licensing system has done a great deal to build and maintain Canada's reputation as a large supplier of consistent high-quality protein wheat. Since the 1960s, the export market for H wheats has not grown as quickly as it has for M and S wheats (table 1).[2] Because of its licensing and grading emphasis on the production of H wheat, Canada has not been able to supply, in any significant manner, the substantial growth in demand for M and S wheats.

Since 1974, a new M wheat variety called HY320 has been tested for agronomic merit by plant scientists across the Canadian Prairies. This variety, which was licensed in Canada only in 1985, has produced yields that, on average, have been 30 percent higher than traditional Canadian H wheats. Historically, Canadian wheat-licensing officials were reluctant to license M wheat like HY320 because of their perception that Canada's reputation as a supplier of consistent, high-quality H wheat might be compromised and because Canada's grain transportation system was already using its full capacity to move only the relatively lower-yielding H wheats to export positions.

Proponents of continued emphasis on H wheat point to the relatively stable demand for H wheat in Japan, western Europe, and the Soviet Union, where such wheat commands a price premium (henceforth referred to as the "protein premium"). They argue that countries that are unwilling, or unable, to pay a price premium for Canada's best H wheat can still purchase lower grades of Canadian H wheat or even high grades of Canadian H wheat that are in excess of the needs of the premium priced markets. On the other hand, those who support large-scale production of several classes of wheat, including HY320, draw attention to the diverse climate and soil conditions that exist within the Canadian Prairies. To take advantage of these diverse conditions, production of a wide range of varieties and classes must be allowed. Furthermore, the growth markets for wheat in the 1980s and beyond could be largely accommodated by M varieties similar to HY320.

The purpose of this paper is to determine whether the historical emphasis on the production of H wheat should be continued in the

[2] Durum wheat is generally considered to be quite a distinct product from any of the other three classes by people in the wheat trade. For this reason, it will not be included in the description and analysis that follow.

light of an increasing world demand for wheat of somewhat different quality (e.g., M wheat). The strong results show that this emphasis has been misplaced since the rates of return from introducing HY320 are very impressive and likely exceed returns from investments in most other agricultural technology endeavors.

## II. Model

Let the availability of agronomically suitable varieties of both H and M wheat on the Prairies be initially represented in figure 1 by the production opportunities locus $x_0y_0$, where any point on the $x_0y_0$ locus represents the combinations of H and M wheat that can be produced from resources originally committed only to the production of H wheat. Assume that the slope of line $R_1$ represents the relative world prices for M and H wheat. Initially M wheats are not licensed in Canada; Prairie farmers cannot produce M wheats. Hence only $y_0$

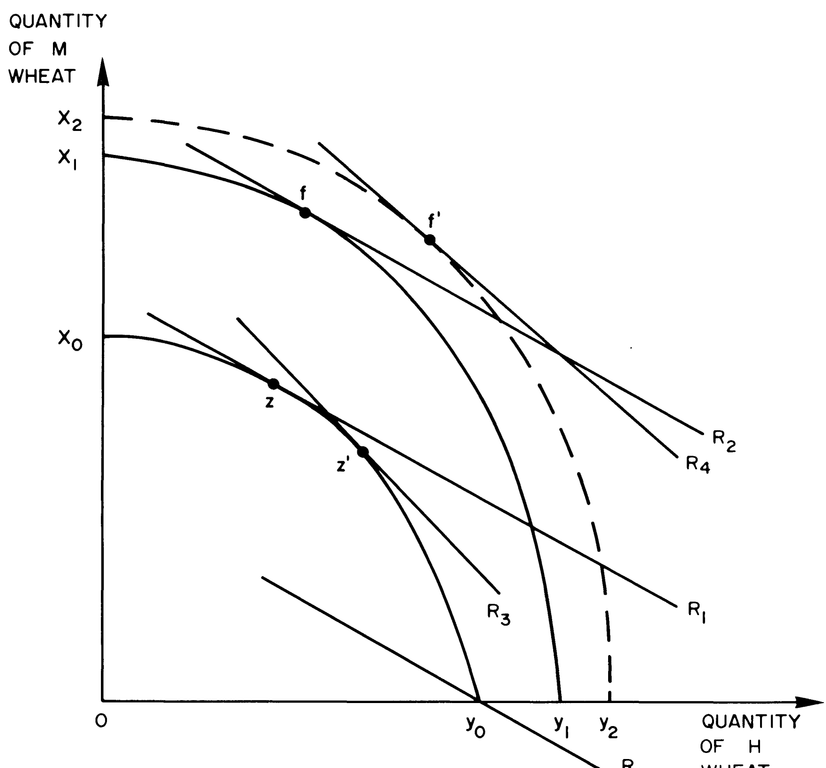


FIG. 1.—Long-term effects of introducing a new class of wheat

amount of H wheat is produced (i.e., a Canadian legal constraint shifts line $R_1$ to line $R_0$ in a parallel fashion).

Now assume that Canada cannot affect the world price of either M or H wheat; the first year that M wheat is licensed in Canada, line $R_0$ shifts outward to line $R_1$ and Prairie farmers are able to plant both M and H wheat varieties using the resources they had initially allocated for wheat production. If the amount of labor and capital resources devoted to wheat cannot change during the first growing season after M wheat is licensed, Prairie wheat production can shift only from $y_0$ to $z$ (i.e., along the $x_0y_0$ locus).

However, this cannot be the final equilibrium point because the total net revenue generated from the initial quantities of labor and capital, measured in either good, is higher at $z$ than it is at $y_0$. In the following growing seasons, additional labor and capital would enter the wheat sector, advancing the production opportunities locus from $x_0y_0$ to $x_1y_1$ and the new wheat output mix to $f$.

Now let us relax the assumption that Canada cannot affect the world price of M or H wheat.[3] Since Canada's market share of the world trade in H wheat is many times higher than its market share of the world trade in M wheat, it is almost certain that Canada has a much bigger effect on world H wheat prices than on world M wheat prices. It is thus reasonable to assume that the reduction in output of Canadian H wheat that occurs as Prairie wheat producers shift to producing some M wheat would cause the world price of H wheat to rise relative to the world price of M wheat. As this happens, the relative price line would become steeper (i.e., line $R_1$ would become as steep as line $R_4$).

If such a price shift took place when we were still on the initial $x_0y_0$ locus, the equilibrium production point would have been at $z'$ instead of $z$ because some farmers who were previously indifferent to producing H or M wheat would now have an economic incentive to produce only H wheat. In this case, the rise in the price of H wheat would have increased the net revenue from the initial set of resources used, above where it would have been at $z$ because the price of H wheat has risen and the price of M wheat has remained constant while costs of production have remained unchanged. This, in turn, would cause an even greater influx of labor and capital than would have occurred had no change in relative prices occurred.

Since such a price shift would be very likely, it is almost certain that the final production opportunities locus would shift beyond $x_1y_1$ to

[3] This is quite likely given the fact that Canada is still the world's leading exporter of H wheat. The exact magnitude of this effect would have to be determined econometrically.

$x_2y_2$ and Prairie wheat production from $y_0$ to $f'$ after all the changes in licensing and relative wheat prices had exerted their full round of effects on wheat sector profitability.[4]

From figure 1, it is obvious that the improvement in Prairie producers' welfare when we move from $y_0$ to $f'$ is more than when we move to $z$ or $z'$; hence if we could calculate the benefits of going from $y_0$ to $z$ or $z'$, we would have a very conservative estimate of what the final benefits would be when the wheat sector reaches the final new equilibrium at $f'$.

With this in mind, we attempted only to estimate the producers' gains from being allowed to move from $y_0$ to $z$ and $z'$. To do this, we used a series of partial equilibrium models to represent the differences in capacity to produce H and M wheat in different Prairie regions and to calculate more easily the initial stages of the general equilibrium model above.

As a first approximation to the estimation of the effects of not licensing M wheats in Canada, consider figure 2. In western Canada some agronomic regions are much better suited to growing H wheats than are others because of differences in climate and soils. Generally, the wetter, more northern regions produce H wheat (designated H3) that is more discolored, shriveled, and lower in protein. Such wheat is not valued as highly in export markets as the more desirably colored, plump, higher-protein H wheat (designated H1) from the drier, more southerly areas.

To simplify the analysis, suppose there are only two regions, where region A grows only H1 and region B is able to produce only H3 because of agroclimatic differences. Assume for the moment that the price of H3 is identical to the price of the higher-yielding M wheat that is unlicensed. In figure 2, at an expected price of $P_{H3}$, region B would clearly produce, if licensed, the higher-yielding M variety at a production level of $Q_{BM}$. The net gain for region B of switching to the new M wheat is area *befb'*—the differences between $S_{BH3}$ (i.e., H wheat grown that has only H3 quality and value) and $S_{BM}$ (i.e., the higher-yielding M supply curve).

Whether or not region A will adopt the new M wheat will depend on the magnitude of the protein price premium. If the protein price premium exceeds $P_{H1} - P'_M$, region A will grow H wheat (i.e., along $S_{AH1}$). If the premium is less than this amount (e.g., $P_{H1} - P_M$), it will switch to producing the higher-yielding M wheat along $S_{AM}$.

If the protein premium is $P_{H1} - P_M$, the net gain from introducing

[4] The reader may notice that the production opportunities locus in fig. 1 shifts outward a greater distance along the M axis than along the H axis. This was done because M wheat varieties are generally more responsive to fertilizer than H wheat varieties.

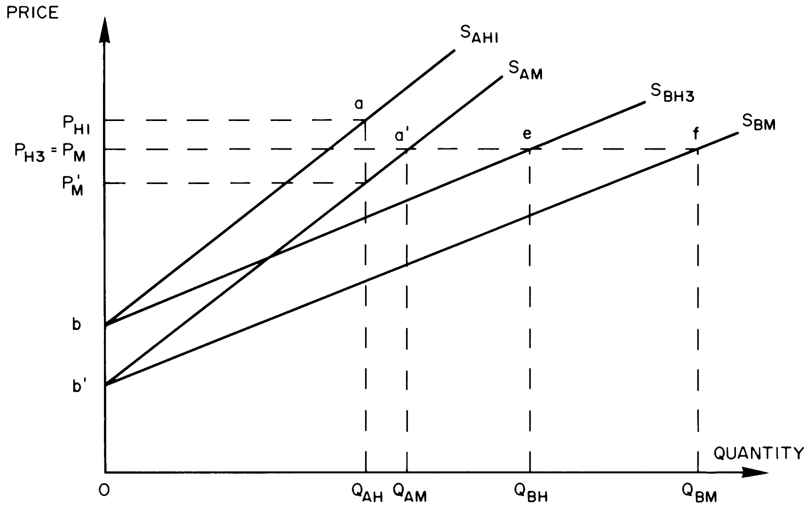


FIG. 2.—Supply of two classes of wheat in two different agroclimatic regions

the M variety is area *befb'* plus the area $P_M a'b' - P_{H1}ab$. Clearly, the gain from licensing the M variety depends on the size of region A versus region B and the magnitude of the protein premium. The smaller the premium and the greater the area of region B relative to region A, the greater are the gains from the introduction of the M variety.

## III. The Economic Cost of Not Licensing HY320

### A. *The Supply Side*

For administrative and statistical purposes, the Canadian Prairies have been divided into a number of crop districts. Annual historical data on the production and quality of H wheat on the basis of these crop districts were available. In addition, extensive test plot data existed, along with actual farm data,[5] from which to infer what the yield and quality of M wheat would have been had it been grown. For each crop district, the projected economic rents from these two classes of wheat were compared to determine the economic benefits that would have accrued if an M wheat variety had been licensed.

Production of M wheat over and above the historical annual H wheat level of production would have to bear additional farm, transport, and handling charges. To incorporate these additional costs into

[5] Actual farm data were available since the CWB had allowed a sample of growers to produce HY320 under a special contract program in 1982, 1983, and 1984.

the model, the projected gross sales value of M wheat was calculated. From this sales value was subtracted the product of additional farm, transport, and handling charges times the production volume of M wheat, over and above the historical annual volume of H wheat production, to produce the gross sales value of M wheat at the farm gate that was comparable to the previously calculated gross sales value of H wheat at the farm gate.

The annual relative yield advantage (RYA) of HY320 over H wheat varied according to the year and the agroclimatic region in question. In 1982, 1983, and 1984, the CWB allowed increasing numbers of farmers to grow HY320 in a special market-testing contract program. One of the conditions of this contract program was that each farmer had to plant both HY320 and a traditional H wheat variety in the same field and use the same cultural practices on both varieties. From the results of these contracts, the CWB calculated the annual RYA of HY320 under farm conditions in each agroclimatic zone.

During and preceding the 3 years of this farm contract program, Canadian crop scientists were also carrying out yield trials to determine the RYA of HY320. Somewhat surprisingly, the data thus produced showed that the RYA of HY320 grown on farms was as much as, or even more than, the RYA calculated from yield trials conducted on research stations. This is illustrated in table 2.

### *B. The Demand Side*

Most crop districts show a year-to-year variation in the percentage of each grade they produce. However, over an average of years, a certain crop district usually produces a certain grade of wheat. For in-

TABLE 2

COMPARISON OF RESEARCH STATION AND FARM YIELDS

| | RESEARCH STATION PLOTS | | REPORTED BY FARMERS | |
|---|---|---|---|---|
| | 1983 | 1984 | 1983 | 1984 |
| All brown soils: | | | | |
| HY320 yield (bushels/acre) | 58.5 | 37.1 | 44.4 | 32.1 |
| Check yield (bushels/acre) | 47.0 | 32.4 | 35.1 | 26.0 |
| RYA* (%) | 24.5 | 14.5 | 26.4 | 23.7 |
| All black and gray soils: | | | | |
| HY320 yield (bushels/acre) | 53.9 | 65.2 | 51.8 | 45.4 |
| Check yield (bushels/acre) | 44.4 | 53.9 | 39.4 | 35.3 |
| RYA* (%) | 21.4 | 21.0 | 31.5 | 28.8 |

SOURCE.—Canadian Wheat Board (1984); Expert Committee on Grain Breeding (1985).
* RYA = (HY320 yield − check yield)/check yield × 100.

TABLE 3

HISTORICAL GRADING PATTERN OF WHEAT IN ALBERTA CROP DISTRICT 7 (1972/73–1981/82)

| Crop Years | Percentage of Total H Wheat Falling into Each Grade | | | | |
|---|---|---|---|---|---|
| | H1 | H2 | H3 | HF | Total |
| 1972/73 | 0 | 10 | 73 | 17 | 100 |
| 1973/74 | 0 | 5 | 43 | 52 | 100 |
| 1974/75 | 0 | 4 | 30 | 66 | 100 |
| 1975/76 | 1 | 21 | 61 | 17 | 100 |
| 1976/77 | 0 | 19 | 75 | 6 | 100 |
| 1977/78 | 0 | 7 | 47 | 46 | 100 |
| 1978/79 | 0 | 3 | 35 | 62 | 100 |
| 1979/80 | 1 | 33 | 54 | 12 | 100 |
| 1980/81 | 0 | 6 | 48 | 46 | 100 |
| 1981/82 | 43 | 36 | 20 | 1 | 100 |
| 1982/83 | 2 | 6 | 55 | 37 | 100 |

SOURCE.—Canadian Wheat Board, "Survey of Stored Grain" (various years).

stance, a northern, relatively high-rainfall area like Alberta crop district 7 generally produces H3 and HF grades of H wheat (table 3).

From historical H wheat grading data, the annual grading pattern of M wheat was projected for each of the crop districts in the Prairies. Although grades for M wheat have yet to be established, several officials of the CGC expressed the view that there would most likely be only two grades of M wheat. Areas that traditionally produce H1 and H3 would likely produce M1 and M2, respectively. In addition, areas producing H2 would likely produce M wheat that would fall half in the H1 grade and half in the H2 grade. Areas that traditionally produce HF would also produce a feed wheat grade of MF.[6]

This grade approximation was based largely on the fact that HY320 and other M wheat generally need more days to mature than the traditional H wheat varieties. One of the main factors influencing the production of different H wheat grades is the weather at harvest time, especially the incidence of rain and frost. Generally, the more northerly agricultural areas of the Prairies have the shortest frost-free period and the greatest probability of rain during harvest. Consequently, these are the areas that produce the greatest portion of the H3 and HF grades. If M wheat were grown in these areas, most of this production would probably fall into the M2 or MF grade.

[6] In Canada, the lowest grade of each class or type of wheat (i.e., "feed" or "F") is used only for animal feed and, as such, normally has the same market value regardless of the class of wheat. Hence the livestock feed industry would not differentiate between HF and MF grades.

*C. Prices*

In any particular crop district, the farm price for each grade of H wheat is the Thunder Bay final realized price for each grade of H wheat minus the handling charge minus the freight charge to the crop district in question.

Once the annual historical farm gate price for each grade of H wheat was calculated, the prices for each grade were multiplied by the percentage of H wheat that fell into each H wheat grade in a given year. This product gave the weighted H wheat farm gate price received annually in each Prairie crop district. An example of the results of these calculations for two crop districts is shown in table 4.

Complementary to the gathering of price data for H wheat was the estimation of the prices of the assumed grades of M wheat in the years under question. Such estimation was difficult because Canada has not sold significant quantities of M wheats. However, about half the total American wheat crop and over 80 percent of the Australian wheat crop consist of M wheats. Exports of Canadian M wheat would generally have sold in the same markets and at the same prices as the equivalent American or Australian wheats just as Canadian H wheats compete with American, Argentinian, and Australian H wheats. Unfortunately, even in the H wheat market, the premiums and discounts between H wheat from different origins were not constant over time.[7] In addition, the premiums and discounts between the various classes of wheat showed even greater variability than those within the H wheat class. The reasons for this are similar but more pronounced than those outlined previously for H wheats from different sources. Table 5 shows that even in a Canadian context this variability within a single class is obvious.

Such variability makes it extremely difficult to mathematically model the world market for M wheat with any degree of accuracy. Various studies have tried to do this but with little apparent success. Because of the repeated lack of success in modeling the demand for and supply of M wheat by other economists (e.g., Schmitz et al. 1981) and because of the extensive data requirements such a study would entail, a much simpler approach was chosen to approximate the prices that Canadian M wheat could have been sold for had it been grown in the period 1972/73 to 1982/83. This approach was originally suggested by several members of the CWB and the CGC. It assumed

[7] This is often due to such factors as (1) changing national economic policies, (2) political considerations, (3) long-term purchase agreements, (4) temporary transportation and storage bottlenecks, (5) changing quality requirements of importers, (6) large importers making erratic but large purchases of certain classes of wheat, (7) erratic weather phenomena like early frost, and (8) annual changes in the quality of an exporter's wheat crop.

TABLE 4

COMPARISON OF THE WEIGHTED FARM GATE PRICE IN SEVERAL CROP DISTRICTS WITH FINAL REALIZED PRICE, THUNDER BAY (Canadian Dollars per Metric Ton)

| | FINAL REALIZED PRICE AT THUNDER BAY | | | | WEIGHTED FARM GATE PRICE | |
|---|---|---|---|---|---|---|
| CROP YEARS | H1 | H2 | H3 | HF | Saskatchewan Crop District 4 | Alberta Crop District 7 |
| 1972/73 | 79.14 | 77.68 | 73.27 | 69.89 | 71.23 | 66.32 |
| 1973/74 | 168.21 | 165.38 | 160.68 | 143.52 | 159.89 | 145.00 |
| 1974/75 | 164.39 | 158.22 | 156.60 | 134.02 | 149.39 | 133.86 |
| 1975/76 | 146.28 | 141.43 | 132.79 | 118.58 | 131.25 | 123.74 |
| 1976/77 | 117.15 | 109.90 | 104.35 | 95.92 | 106.75 | 95.94 |
| 1977/78 | 120.30 | 113.81 | 107.17 | 90.15 | 108.78 | 90.29 |
| 1978/79 | 160.53 | 151.80 | 150.11 | 118.87 | 145.28 | 120.70 |
| 1979/80 | 196.43 | 187.64 | 179.18 | 126.80 | 184.99 | 166.29 |
| 1980/81 | 222.12 | 217.96 | 209.42 | 167.71 | 209.06 | 179.79 |
| 1981/82 | 199.62 | 197.03 | 187.76 | 145.71 | 187.58 | 184.29 |
| 1982/83 | 192.34 | 187.39 | 180.39 | 147.71 | 189.03 | 157.10 |

SOURCE.—Canadian Wheat Board annual reports, "Survey of Stored Grain" (various years), and authors' calculations.

that H1 and H2 would have been extremely close substitutes for each other but that H3 and HF would have filled different market demands.

Variety HY320 is an M wheat and hence would likely be priced similar to H3; however, the protein and gluten strength of HY320 tend to be less than that of H3. This factor suggests that HY320 would have to be priced somewhat less than H3 but certainly above HF. This assumption is further strengthened by the fact that, generally, American Hard Red Winter ordinary grade wheat, an obvious substitute for HY320, was usually priced less than H3 but more than HF.

The expected M2 grade would sell for a discount to M1. There is no way to know precisely how much this discount would have been. It seems reasonable to assume that, in years when the discount between H3 and HF was relatively large, the discount between M1 and M2 would also have been relatively large. Similarly, when there is relatively little difference between H3 and HF, there would likely have been little difference between the prices of M1 and M2. It was arbitrarily decided that the prices of M1 and M2 would have been the price of HF plus ⅔ and ⅓ of the difference between the prices of H3 and HF.[8]

[8] For instance, if the price per metric ton of HF was $145.71 and of H3 was $180.39, then the prices of MF, M2, and M1 were assumed to be $145.71, $157.27, and $168.83, respectively.

TABLE 5

SELECTED ANNUAL CANADIAN H1 AND HF PRICES

| Crop Year | H1* | HF* | Ratio of H1 to HF Price |
|---|---|---|---|
| 1972/73 | 79.14 | 69.83 | 1.13 |
| 1979/80 | 196.43 | 126.82 | 1.55 |
| 1982/83 | 192.34 | 145.71 | 1.32 |

SOURCE.—Canadian Wheat Board annual report, various years.
* Weighted annual price, basis Thunder Bay.

In our analysis, it is assumed that high-yielding M varieties are distinguishable from lower-yielding H wheats grown in Canada. This is the case for HY320. However, certain other varieties are not distinguishable (e.g., Solar). Cases have arisen in which these higher-yielding but lower-protein varieties have been illegally mixed with high-protein H wheat. This contamination problem continues to exist, and perhaps this issue has made the CGC reluctant to license new high-yielding varieties. However, licensing by itself will not make this problem go away. For example, if none of the varieties was licensed, certain farmers would still grow these types of wheat and mix them with high-protein grades. The answer to this problem is not to stop the licensing of high-yielding varieties that are visually distinguishable but rather to implement methods to deter cheating (i.e., the mixing of visually nondistinguishable varieties with high-protein wheat).

## D. *Results*

To empirically estimate the gain, if any, from growing M wheat, the following calculations were carried out for each of the crop districts for each of the 11 crop years between 1972/73 and 1982/83. These calculations incorporate the previously described assumptions and economic relationships farmers would face when choosing between H and M wheat. The results of these calculations allowed us to calculate whether the average acre planted to wheat in a crop district would have been better or worse off, after 11 years, if it had grown only M wheat or only H wheat for the entire 11-year period:

$$\text{GAIN} = NS_{\text{M}} - NS_{\text{H}}, \tag{1}$$

$$NS_{\text{H}} = WP_{\text{H}} \times PR_{\text{H}} - [PR_{\text{H}} \times (TC_S + HC)], \tag{2}$$

$$\begin{aligned} NS_{\text{M}} = {} & WP_{\text{M}} \times PR_{\text{M}} - [PR_{\text{H}} \times (TC_S + HC)] \\ & - [(PR_{\text{M}} - PR_{\text{H}}) \times (TC_{US} + HC + FC)], \end{aligned} \tag{3}$$

$$WP_{H} = (P_{H1} \times G_{H1} + P_{H2} \times G_{H2} + P_{H3} \times G_{H3} + P_{HF} \times G_{HF}), \tag{4}$$

$$WP_{M} = (P_{M1} \times G_{M1} + P_{M2} \times G_{M2} + P_{MF} \times G_{MF}), \tag{5}$$

$$P_{M1} = P_{HF} + \tfrac{2}{3}(P_{H3} - P_{HF}), \tag{6}$$

$$P_{M2} = P_{HF} + \tfrac{1}{3}(P_{H3} - P_{HF}), \tag{7}$$

$$P_{MF} = P_{HF}, \tag{8}$$

$$G_{M1} = G_{H1} + \tfrac{1}{2}G_{H2}, \tag{9}$$

$$G_{M2} = G_{H3} + \tfrac{1}{2}G_{H2}, \tag{10}$$

$$G_{MF} = G_{HF}, \tag{11}$$

$$PR_{M} = PR_{H} \times \text{RYA}, \tag{12}$$

where GAIN refers to net gain, if any, from growing HY320 instead of traditional varieties; *NS* is the net value of sales after appropriate farm freight and handling charges have been deducted; M refers to the new M wheat variety called HY320; H refers to traditional H wheat varieties; *WP* is the weighted price of wheat after taking into account the grading pattern and the price for each grade; *PR* is the production level; $TC_S$ and $TC_{US}$ are the approximate subsidized and nonsubsidized transport costs from the crop district in question to the nearest major port; *HC* is the approximate amount elevator companies would charge for handling grain from the crop district in question to the nearest major port; *FC* is the additional farm cost incurred when growing a higher-yielding variety; $P_{H1}$, $P_{H2}$, $P_{H3}$, and $P_{HF}$ are the prices of first, second, third, and feed grades of H wheat; $P_{M1}$, $P_{M2}$, and $P_{MF}$ are the prices of first, second, and feed grades of M wheat; $G_{H1}$, $G_{H2}$, $G_{H3}$, and $G_{HF}$ are the percentages of the H wheat crop falling into the first, second, third, and feed grades of H wheat; $G_{M1}$, $G_{M2}$, and $G_{MF}$ are the percentages of the total M wheat crop falling into the first, second, and feed grades of M wheat; and RYA is the relative yield advantage of HY320 over H wheat.

In addition, we tested the sensitivity of our results to three additional pricing scenarios because, in making our initial assumptions, we were most uncertain about what the annual relative prices between the various grades of H and M wheat would have been. We chose these pricing scenarios because we felt that they represented the most extreme likely relationships or because the values chosen (e.g., 10 percent) were easy to utilize when explaining the results to the general public. In addition, the price effects that were simulated were

TABLE 6

Elasticity of Foreign Demand for Canadian Wheat (*Edc*)

| Canadian Market Share (*S*) | Elasticity of World for Demand for all Wheat (*Edw*) .5 | 1.0 | 1.5 |
|---|---|---|---|
| | When Elasticity of Supply of Non-Canadian Wheat = .8 | | |
| .1 | 12.2 | 17.2 | 22.2 |
| .2 | 5.7 | 8.2 | 10.7 |
| .4 | 2.5 | 3.7 | 5.0 |
| .6 | 1.4 | 2.2 | 3.0 |
| | When Elasticity of Supply of Non-Canadian Wheat = 1.0 | | |
| .1 | 14.0 | 19.0 | 24.0 |
| .2 | 6.5 | 9.0 | 11.5 |
| .4 | 2.8 | 4.0 | 5.3 |
| .6 | 1.5 | 2.3 | 3.2 |
| | When Elasticity of Supply of Non-Canadian Wheat = 1.2 | | |
| .1 | 15.8 | 20.8 | 15.8 |
| .2 | 7.3 | 9.8 | 12.3 |
| .4 | 3.1 | 4.3 | 5.6 |
| .6 | 1.6 | 2.5 | 3.3 |

Note.—The values for *Edc* are based on the following formula: $Edc = (1/S) \times Edw + [(1 - S)/S] \times Esw$.

well within the range of those predicted by a wide range of estimates of the elasticity of foreign demand for Canadian wheat (table 6).

The four pricing scenarios that we tried included the following: scenario I: prices of various grades of H and M wheat were those appearing in equations (6), (7), and (8); scenario II: all M wheat was sold at the historical HF price (i.e., valued solely as animal feed); scenario III: the protein premium for H1 and H2 would have been 10 percent above what it has been historically because of the Canadian reduction in output of H wheat; scenario IV: the protein premium for H1 and H2 would have been 20 percent above what it had been historically because of the Canadian reduction in the output of H wheat.

Under scenario I (i.e., assuming that M wheat could have been sold at prices competitive with American and Australian M wheat) all crop districts would have been better off if they had grown only M wheat.[9] Thus, in terms of figure 2, the protein premium would not have been sufficiently high to have prevented farmers from shifting all their resources devoted to wheat production from H to M wheat production. These results were obtained even after the nonsubsidized freight rate[10] was paid on the projected volume of M wheat production that was in excess of the historical volume of H wheat production. Under scenario I the value of total farm gate Prairie wheat sales would have increased by 10 percent over what it has been historically if HY320 had been licensed (this is equivalent to an increase of 15–25 percent in Prairie net farm income because all the incremental costs associated with the higher yields were deducted).

Under scenario II the more southerly, drier crop districts would have had higher net returns if they continued to produce H wheat because the value of the protein premium they received for their H wheat was usually higher than the value of the increased yield of M wheat over H wheat. The total value of farm gate Prairie wheat sales was only 1 percent higher than what it had been historically even though the volume of total wheat production had increased by 15 percent.

The results of scenario III were similar to those of scenario II with farm gate Prairie wheat sales increasing by 10 percent over what they had been historically. (However, only 3 percent of this increase was due to switching from H to M wheat by some crop districts. The rest was due to the higher assumed protein premiums for the H1 and H2 grades of H wheat.)

If scenario IV had come to pass, there would have been no economic incentive for most crop districts to switch from H wheat production to M wheat production. In addition to no M wheat production in the southern, drier crop districts, there was no M wheat production in some of the northern, moister crop districts. (In this case, the value of wheat sales at the farm gate was 15 percent higher than what it has been historically, but less than 1 percent of this

[9] It should be recalled that this was the result after a total of 11 crops had been grown. In almost every year, there were situations in which a crop district would have been worse off switching to M wheat; however, the gains made by switching in some years more than compensated for the losses sustained in other years.

[10] The freight rate to move Canadian wheat to export position has been held constant by law since the early 1900s. Any shortfall between this rate and the actual cost has been paid by the Canadian government to the railways and hence has been a transportation subsidy to Canadian farmers who export wheat. Recent and proposed changes in legislation will have farmers paying up to the full freight cost if freight handlings exceed a certain level.

increase was due to the gain caused by shifting from H to M wheat in some crop districts.)

The detailed results of these four pricing scenarios showed that the economic incentive to grow M wheat, expressed as the percentage increase in the value of total wheat sales at the farm gate, depended most on the historical grading pattern an area experienced. The historical grading pattern was, in turn, associated with the agroclimatic zone the crop district was in. Generally, the more southerly, drier (higher-grading) crop districts would have had less incentive to adopt M wheat than the northerly, higher-moisture (low-grading) crop districts. Consequently, the opportunity cost of not licensing M wheat has fallen more heavily on the northerly, higher-moisture crop districts.

### E. *The Costs*

What is the cost to Canada of not licensing M wheat? Taking into account the very conservative approach that was taken, in 1982/83, average farm gate spring wheat sales could have been 5–10 percent higher than they actually were in that crop year if M wheat had been licensed and adopted in those areas of the Prairies where there was an economic incentive to grow this class of wheat (needless to say, on an individual farm basis, this figure could have been higher or lower). In 1982/83, total H wheat production was roughly 22 million metric tons worth at the farm gate about $4 billion.[11] Since the sales value could have been increased by 5–10 percent by allowing some farmers to switch to M wheat, annual net farm income could have been increased by 15–25 percent (i.e., $200–$400 million). Net farm income could have increased by another $75 million if farmers did not have to pay compensatory freight rates on the incremental production that results from growing M wheat. These calculations are summarized in table 7.

To put the loss in net farm income in another perspective, consider the rate of return on investment in plant breeding research from the introduction of HY320. Since the 1960s, Canadian wheat breeders have devoted more and more effort toward developing M wheat varieties. This was because they realized that (1) changing flour-milling technology had lessened the world demand for Canada's traditional H wheat, (2) it was increasingly difficult to develop higher-yielding H wheat varieties given the high quality standards they had to incorpo-

[11] These figures were obtained by rounding off the numbers appearing in the Canadian Wheat Board annual report for the 1982/83 crop year. They include relatively insignificant quantities of winter and soft wheat.

TABLE 7

Approximate Minimum Forgone Farm Gate Wheat Sales (1982/83)

| | Increase in Farm Gate Sales | |
|---|---|---|
| | 5% | 10% |
| Forgone farm gate sales* | $200,000,000 | $400,000,000 |
| Additional nonsubsidized freight paid on incremental M yield† | 75,000,000 | 75,000,000 |
| Net forgone income if all M wheat shipped at subsidized rate | $275,000,000 | $475,000,000 |

Source.—Authors' calculations and Statistics Canada (1984).

Note.—For purposes of comparison, the 1982 realized net income from farming operations is:

| | |
|---|---|
| Manitoba | $ 223,000,000 |
| Saskatchewan | 912,000,000 |
| Alberta | 594,000,000 |
| Prairie total | $1,728,000,000 |

* 5 percent or 10 percent of 1982/83 Canadian Western Red Spring sales of 1982/83 production of 22 million metric tons, valued at $4 billion.

† Equals .16 × 24 million metric tons × $20/metric ton.

rate in any new H wheat crosses, and (3) some areas of the Prairies had never been able to consistently produce high-quality H wheat because of unfavorable agroclimatic conditions. Estimates of the internal and external rates of return from licensing HY320 are shown in table 8.[12] The internal rates of return are indeed impressive, with the upper estimate approaching 95 percent. This is much higher than, for example, the internal rate of return of 35–40 percent calculated by Griliches (1958) in his seminal paper on hybrid corn research. It is also much higher than internal rates of return calculated for the development of most agricultural technologies.[13] This high rate of return from variety development efforts results because of the interplay of two factors: a yield increase from switching to M wheat in some areas and an increased protein premium for the remaining H wheat.

This is a significant conclusion because in the rate-of-return calculation (1) all the research "dry holes" are charged as costs of achieving the gains from HY320, even when the M wheat research program produced some ancillary benefits that have not been taken into account; (2) the RYA of M over H varieties used in this study was based on research station results; the RYA based on farm data was even

[12] The external rate of return is the present value of the benefits expressed as a percentage of the present value of the costs minus 100 percent. The internal rate of return is the compounded annual interest rate that will make the present value of a time stream of benefits just equal to the present value of the associated time stream of costs.

[13] See Ruttan (1982, p. 242) for an excellent summary of research studies.

TABLE 8

ESTIMATED RATES OF RETURN FROM LICENSING HY320 WHEAT

| Research Costs* | Internal Rate of Return (%) | External Rate of Return (%) |
|---|---|---|
| | If Net Farm Wheat Sales Increase by 5% | |
| High cost | 53 | 250 |
| Low cost | 84 | 1,024 |
| | If Net Farm Wheat Sales Increase by 10% | |
| High cost | 62 | 500 |
| Low cost | 93 | 2,036 |

SOURCE.—Authors' calculations.

* Because HY320 was one of many crosses made in the nontraditional wheat-breeding program between 1965 and 1976, it is difficult to separate out exactly how much it cost to develop HY320. For this reason, two extreme assumptions were made regarding research costs. In the low-cost case, it was assumed that it took only 10 percent of this total to develop HY320 wheat. In the high-cost case, it was assumed that it took all the nontraditional wheat-breeding research expenditures from 1965 to 1976 to develop HY320 wheat. Maintenance research was assumed to equal 30 percent of the average research expenditures for 1974, 1975, and 1976. To be conservative, it was assumed that maintenance research would be necessary until 1997, when it was assumed that benefits from HY320 would end. It was also assumed that, from 1977 to 1982, benefits from growing HY320 would be 5, 10, 25, 50, and 100 percent, respectively, of the benefits generated once HY320 was fully adopted. This was to simulate the fact that it takes a number of years before a variety reaches its maximum adoption level. Benefits were assumed to extend 20 years, starting in 1977. Benefits after 1984 were assumed to equal the average level of benefits for 1982, 1983, and 1984.

higher than the RYA on research stations; and (3) we did not allow any additional resources to flow into the wheat sector, over and above the historical level of resources devoted to wheat, in any of the 11 years of the simulations (i.e., our model in fig. 1 shows that this treatment certainly underestimates the rate-of-return calculation).

## IV. Conclusions

This paper has calculated the cost of a licensing regulation that prevented Canadian wheat producers from adopting new, high-yielding grain technologies. Most Canadian wheat producers appear to have lost net income because of this regulation written in stone. However, it is not clear who were the beneficiaries of such a rigid policy. Canadian grain grading and handling personnel may have experienced a very small welfare gain in that such licensing regulations reduced the number of grades and classes of wheat they had to maintain. Foreign producers of M wheat had probably the most to gain from such restrictive licensing on the part of Canada.

The internal rate of return from research if the licensing constraint were removed is indeed impressive. It follows that sizable costs are incurred from stopping the adoption of new technologies both from lost opportunities and from the actual past research expenditures that were incurred to make the new technologies available. This paper supports Ruttan's (1982) contention that there is underinvestment in agricultural research. However, our paper points out that this is the case only if institutions change regulations so that the adoption of the new technologies is possible.

The remaining puzzle is why this high-yielding technology was not adopted sooner on the Canadian Prairies. An answer appears to be that the information as to the potential payoff was not known by industry officials and regulators. Other reasons include the continuation issue raised earlier.

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