TECHNOLOGY AND STRUCTURAL CHANGE IN ALBERTA CEREAL AGRICULTURE

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Abstract

Structural change and technology within the agriculture and food system in Alberta are becoming more complex as agriculture industrializes. This relationship is neither simultaneous nor unique according to work done on commercial cereal farms in central Alberta. The nature of the relationship appears to be one of periodic reversal of causality. Technology, characterised mainly as mechanical and chemical, shaped structure during the period represented by the 1971 census. Biotechnology is beginning now to have its own effect on fixed factor proportions distinct from that of mechanical technology. Mechanical technology change is having a greater effect on capital/labor ratios in 1986 than in 1971. Fixed factor proportions, as observed in 1986, appear to be becoming limiting to technology.

Disturbances to the economic structure of agriculture by technological change normally bring reaction to preserve the status quo. The reaction, taking the form of subsidies and credit policies, may be counter productive to technological change required for competition in world markets during periods when structure determines technology. Perhaps the most important of these structural changes has been the declining rural equity in farm businesses which is slowly changing the self employed nature of agriculture to that of the owner/employee organisation of urban economies. This change makes farm family income increasingly dependent on off farm employment in rural and periurban areas.

The results from this study lead to the conclusion that government policies to limit the consolidation of farms are more inhibiting now to technological change than they used to be. With the emergence of interest in agricultural free trade, it is more essential than ever before to distinguish between subsidies which compensate for hurt from hostile weather or foreign domestic policies, from those subsidies which address structural hurt from technological progress.

The Issues

The agriculture sector in Alberta is undergoing massive structural change. The changes in concentration of land ownership, increased tenancy, higher capital requirements, declining equity and greater requirements for industrial inputs are causing economic stress on farms. Wide weather variation from long term averages and large price fluctuations have added to this distress and may have had some influence on the structural changes. However, changing technology may be considered as the more profound underlying force behind the structural changes underway in grain production. This paper reports on some research which looked into the relationships between technology and structure.

Intuitive reasoning suggests that technology shapes structure. The convention in Alberta as in other jurisdictions within developed countries is to invest in research, promote technical adoption and then to compensate farmers for consequent structural stress. Compensation may be in the form of debt restructuring, tax relief, market protection and assorted provincial family farm focussed support programs. Other compensation programs also address the impacts of epiphenominal hostility toward the system from the economic or ecospheric environments. Examples of these programs are the Special Grains Program, Western Grain Stabilisation Agreement and the Drought Assistance Program. If there are relationships between structure and technology, then these programs to preserve structure, or at least to slow down the rate of structural change to politically tolerable levels, together with the structural consequences of technological change may be influencing future technology in agriculture. Constant technological change is a prerequisite to competitive action to improve Alberta's market shares in various commodity markets.

The issues may be identified more easily by using systems analysis. An agricultural and food system (AFS) is a collection of human activities modifying natural biospheric processes to transform solar energy into human food. These human activities are harmonised by economic, social and political behaviour and motivated by individual aspirations as well as by forces operating outside the system. Since the industrial revolution, much of the technology used in agriculture has originated from outside the system in forms molded by the same economic, social and political forces. It is thought that this inflow of industrial technology is one of the reasons for structural change toward an industrial structure for the agricultural economy. It would appear also that this technology may be making agriculture more vulnerable to its economic and political environments.

Economies of size in both the backward and forward linkages to agriculture appear as monopoly/monopsony behaviour. Examples are high levels of concentration in food retailing and livestock processing and in agricultural chemicals, machinery manufacturing and financial services. Economies of size are present also in some types of farm enterprises emerging most clearly in egg and poultry production. There is strong evidence that economies of size are now characteristic of many commodity production processes in agriculture such as cereal production. The limitations to further size economies with current technologies, appear to lie with space, with operational timeliness for field crops and with management intensity for livestock. Vertical integration of primary production within the food parts of the system is confined to special cases of vegetables and fruits for processing, to market niches for livestock products such as eggs and processed meats, and to greenhouse operations. Economies of size and the resulting rearrangement of enterprise ownership and market conduct have, so far, not removed the family context from Canadian farming.

Family farming may be viewed as farming with the majority of inputs controlled by a social unit based on a conjugal relationship. This way of farming has evolved over the 12,000 year history of agriculture, primarily it would appear, because it is well suited to coping with the open boundary of the AFS within the natural (ecospheric) environment. The family decision unit responds to changing weather and pest problems in a timely way. One could also hypothesize that societies and their governing bodies prefer this atomistic structure as manageable and exploitable for its lack of inter family cohesiveness which prevents concentration and monopoly power over food production.

In Canada, farm family prosperity often has been preserved through several generations, especially where growth and development of the family farm has not slowed down prior to transfer of responsibility from father to son. However, this prosperity has been accompanied by steady out migration up until the mid seventies. Canada has enjoyed rapid growth and development in the non-farm economy, which combined with post war improvements in rural education, has generated the high opportunity costs for farm youth prompting their migration. The capital intensity of farm operations and opportunity costs for equity also constitute a barrier to entry. The attraction to non-farm employment is particularly great for people whose farms have experienced little or no development for some years due to age of the operator, resource endowment, psychological distress in the family, lack of aptitude for self employment, preponderance of social/cultural values over economic values or active local competition for land. Farm family members now account for only about four percent of the Canadian population.

A minority of farm families, as in any society, are innovative; inventing and adopting technologies which bring economies of size and thus wider margins in their price-taker market environment. A large number of family units do not innovate, but rather follow the leaders often after several years; many others don't follow. In this context, the latter could be cast as residuals in the process of innovation.

Public policy in Canada has protected farm incomes of innovators, followers and residuals indescriminantly. Economically successful families on this policy environment are those who have responded to changes in their economic environment. It is not clear if those remaining in agriculture, but not participating actively in its development, are residuals of the technological process and/or of larger global economic forces. However, there may be some connection between response induced structural change and technology. The latter may reflect or even embody the cultural values and economic environment of its origin. And that origin appears to have become international, intersectoral and industrial.

Definitions and Concepts

Structure is a notion lacking consensus of definition. As a result, pursuing the topic of restructuring or structural change tends to be rhetorical. Ehrensaft and Bollman cut through this rhetoric and note five aspects of structure: 1) number and size distribution of farms, 2) degree of commodity specialization, 3) internal organisation of farms in terms of fixed factor proportions, legal organisation, land tenure and locus of decision making, 4) entry and exit patterns, and 5) socio-economic characteristics of farms. These workers note also that structure may be examined at different levels of aggregation including commodities and regions.

Structure may be more fundamentally viewed as a definition of proportions with each different set of proportions constituting a different structure. The economic structure of agriculture viewed this way includes fixed factor proportions, variable/fixed cost proportions and size, ownership and financial equity proportions, commodity output proportions (specialisation) and concentration of markets and production (participation). These structural attributes are observable and can be measured.

Technology is more difficult than structure to define. The concept remains nebulous often treated as a residual or as a productivity index derivative. Current thinking about the origin of technology appears to fall in with that of Hayami and Ruttan concerning factor scarcities and induced innovation. Conceptually, technology is the accummulation of human knowledge about how to do things. The replacement of methods based on less understanding by methods requiring greater understanding constitutes technological change. This replacement process is thought to be purposeful, though the discovery of improved understanding may originate by accident as well as by design.

Interest in the ways structure and technology affect each other arises from two social concerns. The first concern is for a safe, nutritious, reliable and affordable food supply. Societies, in general, especially those removed from the land, regard food security as an integral part of national security and internal stability. The second concern is the value placed by society on its rural heritage of freedom and democracy. More recently it appears that ecological issues including maintenance of a rural domain also have become important, especially in Europe. In Canada, the fiscal, social and economic viability of rural communities may not yet be perceived as a problem by urban people because the rural areas are not seen as intrinsic to urban life. Consequently, the main concern, especially in western Canada, about structure/technology pressures on rural economies is confined to rural communities.

Concern over the structure-technology interface from an economic researcher's perspective is in terms of delineating the forces that drive the AFS. Understanding this relationship would enable both the economist and other disciplines to estimate the directional consequences of both technological and structural change. Quantification of the structure-technology interface requires and enables long-run analysis to improve the perspective for government interventions often prompted by short-run structural crises in agriculture.

Relationships

The relationship between structure and technology seems to be more of a collection of multi-directional feedback loops than of a causal relationships. In work just completed, we have examined the simultaneity of the relationship and the hypothesis that the larger economic condition of agriculture influences this relationship. It was postulated that structure and technology relationships may not remain the same under all economic environments to the AFS. The hypothesis was that structure shapes technological change during periods of economic stress and pessimism for agriculture and vice versa. The hypotheses were tested with primary farm level data obtained using small sample techniques in east central Alberta.

Structural and technological data were obtained for 1971, 1981 and 1986 from a random sample of farms. The general economic situations in the periods preceding each of the three years were viewed as bouyant, strong and declining respectively. Using the Wu Hausman test of endogeneity, it was determined that simultaneity of the structure/technology relationship did not exist. The implications of such a phenomenon for public policy which promotes technology and addresses prices, incomes and structural concerns are interesting. The structural variables used to test the hypothesis were three different fixed factor proportions. The technology proxies were horsepower of the largest tractor representing mechanical technology, a fertilizer applications method index representing biotechnology, and land productivity and cropping intensity also representing biotechnology.

All three structural measures (fixed factor proportions) in 1971 were influenced significantly by the mechanical technology proxy. The inverse relationship did not hold (Tables 1 and 2). In 1986, both the mechanical and biological technology proxies explained a significant proportion of the variation in the fixed factor proportions involving capital. However, in contrast to the 1971 situation inverse relationships held for the biotechnology proxies only.

No similar relationships, with one exception, were established for 1981 due to unusually high variances for the structural variables. These high variances would be consistent with structure in transition, suggesting that 1981 was a time of substantial adjustment in agriculture. The exception in

Table 1. Effect of Technology on Structure for a Sample of Central Alberta Commercial Grain Farms 1971 and 1986.

Structure Variable (dependent)	Elasticities 1971 Mech Tech	Elasticities 1971 Bio Tech	Elasticities 1986 Mech Tech	Elasticities 1986 Bio Tech
Capital/labour	1.42 (4.88)***	0	1.56 (4.09)***	0.39 (2.01)*
Land/labour	0.55 (3.57)***	-0.20 (-1.72)*	0	0
Capital/land	0.87 (3.10)***	0	1.16 (2.99)***	0.66 (3.38)***

* 90%, ** 95% and *** 99% level of confidence. Numbers in parentheses are t values.

Table 2. Effect of Structure on Technology for a Sample of Central Alberta Commercial Grain Farms 1971 and 1986.

Technology Variable (dependent)	Elasticities 1971 Land/ Labour	Elasticities 1971 Capital/ Labour	Elasticities 1986 Land/ Labour	Elasticities 1986 Capital/ Labour
Land Productivity	-0.68 (-2.30)**	0	-0.49 (-2.71)**	0.40 (3.23)***
Fertilizer Application	0	0	0.24 (2.89)***	0
Cropping Intensity	0	0.17 (2.35)**	0	0.16 (2.10)**

* 90%, ** 95% and *** 99% level of confidence. Numbers in parentheses are t values.

1981 was that fertilizer application technology was influenced by the capital labour proportion.

The structural elasticities for the mechanical technology proxy were 1.42 in 1971 increasing to 1.56 for the capital labour ratio in 1986. A larger increase in the mechanical technology elasticity over the fifteen years was obtained for the capital/land ratio. The capital cost of mechanical technology and/or labour substitution process was still increasing in real terms per unit of draught power. Cropping intensity as a proxy for biological technology had low elasticities, 0.16 - 0.17, unchanging and significant for capital labour proportions (Table 2). The significance of the biotechnology proxies in 1986 in the capital related structural proportions suggests only that biotechnology may have structural implications not generically different to those of mechanical technology.

The technology elasticities for structure reported in Table 2 indicate that the land operated per person year of labour has a negative land productivity elasticity of -0.68 in 1971 becoming less negative to -0.49 in 1986. These observations suggest that labour extensive structures may be becoming less of an obstacle to biological technology adoption, reflecting qualitative changes in available technology.

These results suggest three tendencies in structure/technology relationships over the fifteen years. First, the structure/technology linkages while not simultaneous are increasingly complex over time and hence as the industrialization of agriculture progresses. This tendency is confirmed by weaker Wu Hausman tests in 1986 than in 1971 and by the appearance of more variables in the 1986 models. The tendency is also confirmed by the bidirectional relationships in 1986 which were tested for 1971 but found absent.

The second tendency is for yields and the method of fertilizer application to figure more prominently as technology proxies in 1986 than does horsepower. Cropping intensity did not prove significant in any of the structural functions. This evidence is particularly associated with the amount of land cropped per unit of labour. This tendency supports the now widespread perception that in the process of industrialization, biological technology is surplanting mechanical technology in structure technology relationships.

The third tendency drawn directly from the hypothesis is that structure was being shaped by technology leading up to 1971 and probably during the seventies decade of rapid growth of agriculture and relatively buoyant times, weak late sixties prices not withstanding. By 1986 either the relationship was in the process of reversing or was becoming simultaneous.

The interesting policy questions alluded to earlier arise from the effects of agricultural policies on structure and on technology. It may be recalled that for prairie agriculture, technological change is critical to competitiveness on international markets. The consequence of lagging behind is not so much in terms of declining market shares as in terms of declining real incomes of farm families as attempts are made to maintain market shares. Agricultural support programs may not only be viewed as efforts to correct these income consequences but as inhibitors of technological change through rigidification of structure. Even credit policies may be counter productive because their adverse effect on structural flexibility may be stronger than their enablement of technological change. Certainly policy inertia, the add-on phenomenon and muddling through processes at the federal and provincial levels do not acknowledge any evolution in structure/technology relationships.

The policy implications for rural economies arising from structure/technology relationships for agriculture lie along the boundaries of the AFS. Industrial technology in agriculture is of urban origin. Consequently labour is displaced putting downward pressure on rural wage rates and the volume of rural commerce. Economies of size and declining rural equity in agriculture are promoting consolidation of commodity assembly services and replacing local financial services by more sophisticated urban services. Specialization of agricultural enterprises is making rural economies less stable and more dependent on government sponsored institutions and subsidies, thereby lessening the autonomy of rural communities.

It would appear that rural attitudes and skills are not as well suited to working within urban driven institutions compared to problem solving in home-made autonomous community arrangements. For example, Alberta's Rural Electrification Associations have experienced difficulty working with the power companies and government departments which service the rural electrical distribution networks. The interplay of structure and technology in agriculture has reshaped the boundaries of the AFS with the rural economy and extended its former dependence on agriculture to include a new dependence on remote, urban institutions, both economic and government.

Dealing with these issues by means of public policy is difficult because the timing of political processes doesn't seem to match the dynamics of structural change and technology. Policy processes are reactive and responsive to disturbance of the structural status quo. It would seem that both agricultural technology and the increasingly open boundary between rural economies and the industrial/macroeconomic environments are generating the structural change. Rural people belong to a predominantly self-employed economy and hence may resist additional government intervention longer than do urban people. Consequently, it appears to be difficult to develop goal directed policy for rural development unless urbanization is accepted or the rural economy attempts to isolate itself. The latter option compromises the technological development of agriculture and its ability to compete in international markets. The former involves costs well beyond the fiscal base of the rural economy.

Conclusions and Further Research

Economic structure and technology are consequences of human behaviour on the farm and in the political and economic environment to agriculture. Investigation of this behaviour and the structure/technology relationships raises a number of questions common to all proxy situations. The behaviour is inherently variable and human know how is difficult to quantify. However, this research has demonstrated that structure may be measured through primary observation as opposed to manipulation of economic aggregates. Furthermore, proxy measures for technology in cereal agriculture are possible and their behaviour conforms to intuition. Simple mathematical expressions may be successfully estimated to generate technology elasticities of structural change and vice versa.

It may also be concluded that structure/technology relationships within the cereal agriculture production system in Alberta change with time. The impact of mechanical technology on capital/labour substitution has been growing over the past fifteen years. At the same time the influence of biotechnology on structure, absent fifteen years ago is emerging as a distinct element in structural change. The steady increase in capital requirements on farms due to technology is clearly part of the cause of financial stress, as both farmers and their Provincial government choose debt financing as the means of maintaining momentum of technical change.

The research also identifies an effect of structural change on technology. Cropping intensity increases at about a fifth of the rate of change in the capital labour ratio. Policies that enhance the retention of labour in agriculture limit increases in cropping intensity. Land productivity in 1986 was less adversely affected by the land/labour ratio than in 1971. Technological change in cereal production during the fifteen year period is less inhibited now on large acreage farms. Government policies to limit the consolidation of farms are more inhibiting to technological change than they used to be. Thus the importance of analyzing the trade off between compensation for structural hurt and the need to maintain a competitive agriculture is more necessary now than fifteen years ago. Failure to compete successfully for market share may be predicted to increase political pressure for subsidies in a freer trade world as market share is gained at the expense of standards of living on Alberta's grain farms. It becomes essential to distinguish between agricultural support programs which offset the hurt from hostile weather or trading practices in the environment to the cereal agriculture system, from those programs which address structural hurt related to technological change.

Bibliography

Agriculture Canada. Agricultural Technology Transfer: A Case Study. August, 1986.

Antle, J.M. "The Structure of U.S. Agricultural Technology, 1910-78." *American Journal of Agricultural Economics*, November, 1984, pp. 414-421.

Apedaile, L.P. and W.Z. Zhang. "Family Farms, Prospects for Agricultural Development in Canada and China." Proceedings of a Rural Development Symposium, IAAE, CAAE and CAASS, Beijing, October, 1987.

Babb, E. "Some Causes of Structural Change in U.S. Agriculture." *Structure Issues of American Agriculture*. USDA. Washington, 1979.

Boulding, K. The Economy as an Ecosystem. *Systems Economics*, edited by K.A. Fox and D.G. Miles, Iowa State University Press, 1987, p. 9.

Brewster, D.E., Rasmussen, W.D., and Youngberg. (ed). Farms in Transition. Iowa State University Press, 1983.

Brinkman, G.L. and Warley, T.K. Structural Change in Canadian Agriculture: A Perspective. Regional Development Branch, Agriculture Canada.

Brown, Murray. On the Theory and Measurement of Technological Change. Cambridge: George Washington University Press. 1968.

Buttel, F.H. Beyond the Family Farm. *Technology and Social Change in Rural Areas*, G.F. Summers, ed. Westview Press, 1983.

Domar, E. "On the Measurement of Technological Change." *Economic Journal*, 71: 709-729 (1961).

Ehrensaft, P. and Bollman, R.D. Structure and Concentration in Agriculture: A Micro-analysis of the Census of Agriculture. Paper prepared for presentation to the Annual Meeting of the Canadian Sociology and Anthropology Assn., June 2, 1983. pp. 3-4.

Lee, Jung-Hwan. "A Review of the Theory of Technological Change in Agriculture: Biases and Substitutability." *Jounral of Rural Development*. 4 (June 1981): 55-66.

Lu, Yao-Chi. "Technological Change and Structure." *Structure Issues of American Agriculture*. USDA. Washington, 1979, pp. 121-126.

Packer, K. Structural Changes in Alberta Cereal Agriculture Systems Between 1971 and 1981. Unpublished M.Sc. Thesis. Department of Rural Economy, University of Alberta, 1986.

Peterson, W. and Hayami, Y. "Technical Change in Agriculture." in *A Survey of Agricultural Economics Literature*. Vol. 1.

Ruud, L. "Structure and Technology on Alberta Grain Farms." Unpublished M.Sc. Thesis. Department of Rural Economy, University of Alberta, 1988.

Ruthenberg, H. Farming Systems in the Tropics. Oxford University Press, 1976.

Sellekaerts, W. and Sellekaerts, B. "Technical Change, Capital Formation and Capacity Unemployment in the U.S." *Eastern Economic Journal*, July/Sept., 1984, pp. 231-241.

Solow, R.M. "Technical Progress, Capital Formation, and Economic Growth." *American Economic*

Review, 52: 76-86, May 1962.

U.S. Congress: Office of Technology Assessment. Technology, Public Policy, and the Changing Structure of American Agriculture. U.S. Government Printing Office, March 1986.

USDA. A Time to Choose: Summary Report on the Structure of Agriculture. United States Department of Agriculture, Washington, 1981.

Veeman, T. Structural Change in Prairie Agriculture: An Overview of its Nature and Causes. The University of Alberta, June, 1986.

Zilberman, D. "Technological Change, Government Policies, and Exhaustible Resources in Agriculture." *American Journal of Agricultural Economics*, December, 1984.