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Preface

Agricultural Finance Review (*AFR*) provides a forum for discussion of research, extension, and teaching issues in agricultural finance. This publication contains articles contributed by scholars in the field and refereed by peers.

Volume 43 was the first to be published at Cornell University. The previous 42 volumes were published by the United States Department of Agriculture. *AFR* was begun in 1938 by Norman J. Wall and Fred L. Garlock, whose professional careers helped shape early agricultural finance research. Professional interest in agricultural finance has continued to grow over the years, involving more people and a greater diversity in research topics, methods of analysis, and degree of sophistication. We are pleased to be a part of that continuing development. We invite your suggestions for improvement.

AFR was originally an annual publication. Starting with volume 61, Spring and Fall issues are published. The *AFR* web page can be accessed at http://afr.aem.cornell.edu/. Abstracts of current issues and pdf files of back issues since 1995 are available.

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Manuscripts will be accepted at any time.

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J. D. Black: A Biography

Calum G. Turvey

J. D. Black was one of those catalytic scholars of the early to mid-20th century who went by the label of an agricultural economist and could see interdisciplinary links with astonishing clarity. While Black was not in the traditional sense a specialist in agricultural finance, much of what we know today in terms of the integration of production economics, farm management, and agricultural finance evolved in one way or another from Black's copious writings on the subjects. Much of his contribution has been lost to history and the natural decay of academic citations, but, as documented throughout this biography, his influence on the academic and practical aspects of the production, farm management, and agricultural finance triumvirate pervades to this day.

John D. Black retired from Harvard University in 1954. Since 1927, he had been a dominant force in that department and, following in the footsteps of Thomas Nixon Carver, helped build its academic and graduate program in agricultural economics to one of international prominence in the 1930s and 1940s—one that would compete, as scholarly competition goes, with the University of Minnesota from where he was lured, and the University of Wisconsin from where he had graduated in 1918 at the age of 35.[1]

John D. Black, 1883–1960
[Image from *Economics for Agriculture: Selected Writings of John D. Black*, J. P. Cavin, editor (Cambridge, MA: Harvard University Press, 1959).]

Black was born June 6, 1883, the fourth of 10 children, in a log house on the original family farm in Cambridge, Wisconsin, to Robert and Margaret Black. Of very modest means, his parents pushed academics and education on all of the children, at one point moving to a farm near Fort Atkinson, Wisconsin, for the sole purpose of having access to a high school within city limits.

Of the 10 children, two brothers died as teenagers, and another died on the battlefields of France in 1918 shortly after writing to a friend, "To be trampled down in the fight that is to lead to a victory for 'true democracy' is a sufficient accomplishment for one poor mortal, so let come what may." By then John Black was

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[1] Much of Black's life history was obtained from Galbraith's (1959) portrait of J. D. Black, as published in the festschrift book compiled in his honor and edited by J. P. Cavin.

already studying at Wisconsin, and despite the tragedies, all but one of his siblings graduated from high school and three went on to earn graduate degrees.

Black was in no rush to continue with academics after high school. In 1903 he attended Oshkosh Normal School, and in 1905 started to teach high school algebra, botany, and physical geography while also coaching athletic teams. In 1907 he attended the University of Wisconsin in Madison to study English, and after receiving first-class honors, completed his M.A. in1910.

Between 1910 and 1915, when he began studying agricultural economics, Black taught at Western Reserve University in Cleveland, Ohio, and at the Michigan College of Mines at Houghton. At the latter institution he taught English to engineering students and became increasingly interested in the social sciences, largely because of the influence of sociologists and economists at Western Reserve University. Labor conditions and strife at the mines led Black to consider studying labor economics, but after taking a summer session course taught by Wisconsin professor B. H. Hibbard, he decided on agricultural economics.

Black thrived at Wisconsin, which was one of the indisputable academic arenas in the field of study at the time with a faculty including J. R. Commons, R. T. Ely, W. A. Scott, E. A. Ross, H. C. Taylor, and B. H. Hibbard. Independent of mind, Black would tolerate teachings in economics and sociology even if he disagreed, and directed his attention to classical paradigms. He focused on markets and the firm by reading Marshall, and became sympathetic to institutional and social economics by reading Veblen.

Of the faculty members in 1915 at Wisconsin, probably H. C. Taylor was most influential in guiding Black toward developing a field of study that would ultimately become known as production economics. Black's thesis was titled "Land Tenure in Wisconsin," and the results were eventually published in a couple of bulletins with H. C. Taylor and B. H. Hibbard as coauthors.

Upon completion of his dissertation, Black joined the Department of Agricultural Economics at the University of Minnesota as an assistant professor of economics, rising to the rank of associate professor in six months, full professor after two and one-half years, and head of the division of agricultural economics from the start. The rise of Minnesota's stature in agricultural economics paralleled Black's career ascent. By the time Black left for Harvard, the faculty complement—negligible when he first started—had continually increased in size and stature with additions such as Holbrook Working and H. B. Price, among others. Meanwhile, graduate student numbers increased from three in 1918 to the largest number of graduate students in any discipline on the St. Paul campus. By 1925, J. D. Black joined with Cornell's George F. Warren and Iowa State's Edwin G. Nourse as one of the most influential agricultural economists in the United States (Galbraith, 1959).

Black's reputation continued to flourish after he moved to Harvard to replace T. N. Carver. Carver was a leading (agricultural) economist of the day and, with Cornell's G. F. Warren, was one of the key proponents of the 1919 merger between the American Farm Economics Association and the American Farm Management Association to form the American Farm Economics Association. It was Carver who initiated study in agricultural economics at Harvard in 1903, only the second department to do so in the United States. But in 1929, when the Social Sciences Research Council provided five-year doctoral fellowships for study in agricultural economics, 45 of 120 recipients ended up at Harvard studying agricultural economics and rural sociology under Black (Galbraith, 1959; Mason and Lamont, 1982). Black was then able to increase the complement of faculty and course offerings with Murray Benedict, John Cassels, and John Kenneth Galbraith.

Methods in Production Economics and Contributions to Quantitative Analyses

Black's lifelong interest in research methods and procedure no doubt stemmed from his studies and writings that ultimately defined the field of production economics. Production economics evolved from the study of farm management by W. J. Spillman from the USDA in 1902, followed closely by cost studies conducted at the University of Minnesota and business analysis surveys at Cornell.[2] These cost studies provided recommendations about farm management but operated outside of economics.

In 1905, H. C. Taylor, who would eventually mentor Black in his doctoral studies at the University of Wisconsin, wrote *An Introduction to the Study of Agricultural Economics*, and T. N. Carver examined the economics of variable proportions in his *Principles of Rural Economics* textbook in 1911. Bit by bit, the principles that now make up the foundation of modern production economics were developed in an almost piecemeal fashion.

Black's contribution started with his interest in input-output relationships around 1922, and he published "Input as Related to Output in Farm Organization and Cost-of-Production Studies" in collaboration with Tolley and Ezekiel in 1924, with Ezekiel given credit for developing the method of least squares (see Fox, 1986). Their study investigated single-variable physical relationships for inputs measured not in terms of physical output but in terms of enterprise returns. This work is also one of the earliest applications of regression analysis to problems of agricultural production, providing a hog production function exhibiting diminishing returns in terms of feed and weight gain.

[2] Johnson and Bachman (1959) provide an overview of the early development of production economics and Black's place in its early history.

Many years later, Heady and Dillon (1961) would write, "While such concepts of isoclines, isoquants, marginal rates of substitution, and production surface had not yet come into the literature, these early agricultural economists did come close to producing them in their analyses" (p. 26). Noting that the first publication of a production function for agriculture was contributed by K. Kamiya in 1941 in Japan, and the first U.S. study was authored by Heady in 1946, Heady and Dillon wondered what caused the time lapse between these and the work of Tolley, Black, and Ezekiel in 1924.

In 1926, Black published *Introduction to Production Economics*, the first complete synthesis of the subject matter that linked concepts of the production function and diminishing marginal productivity, comparative advantage, joint production relationships, resource allocation, crop and enterprise selection, economic efficiency, and so on. Furthermore, Black went beyond the individual farm to show how the economics of production could be used in aggregated form to make statements about the agricultural economy in general. This was a point of departure from the works of G. F. Warren and the Cornell agricultural economists who relied heavily on survey data.

T. W. Schultz, taking Black's lead, levied two general criticisms of farm management research, the first being that farm management research (in 1939) did not provide guidance to entrepreneurial decision making in times of change, and second that farm management did not have a mechanism for integration into the general economy. Black recognized these deficiencies in the 1920s and understood that such shortcomings could be alleviated to some extent by quantitative means.

Starting in 1929, Black, under contract with the Brookings Institution, undertook to summarize the quantitative tools applied to agricultural economics and prodigiously released 21 different "scopes and methods" papers with varied authorship in different research fields, including (to list but a few) "Research in Public Finance in Relation to Agriculture" (1931), "Research in Agricultural Credit" (1931), "Research in Agricultural Land Utilization" (1931), "Research Relating to Farm Management" (1932), "Research in Agricultural Land Tenure" (1933), "Research in Agricultural Cooperation" (1933), "Research Relating to Agricultural Income" (1933), and "Research in Agricultural Index Numbers" (1938), the latter of which was no doubt a concluding point to his 1927 missive "Agriculture Now?"

Suddenly there was an explosion of research as concepts from *Introduction to Production Economics* were accepted and expanded. Schultz's (1939) opening line in his "Theory of the Firm and Farm Management Research," for example, claimed that farm management research consumed more personnel and resources than any other branch of agricultural economics.

Agricultural Reform and Readjustment

Production economics as defined by Black and his colleagues held great influence during the depression era years, and indeed much of the work done under the New Deal, whether successful or not, could not have been accomplished had the principles not been set in place by Black in his 1926 book on production economics and his 1929 volume on agricultural reform. Black's drive it seems was centered on agricultural conditions of the day. Much of what he wrote about and much of why he wrote was prompted by the immediacy of required actions for policy reforms and considerations.

Black was very much concerned with the farmer's plight and how his lot faired with the nonfarm sector relative to purchasing power and the industrial wage. An example can be found in "Agriculture Now?" published in 1927; another can be found in conjunction with his studies on parity (Black and MacDonald, 1944).

Black's sympathies extended to the political arena, as observed in his economic dissection and autopsy of the McNary-Haugen Movement in 1928, which purported to protect U.S. prices using tariffs, duties, supply management, and dumping. If we can properly read this missive and interpret fully what lies between the lines, we would come away with the impression that Black was sympathetic to the "agricultural bloc"—a political movement of sorts to mount an affront to the domination of agriculture's affairs and the affairs of the country by commercial and industrial interests.

Nevertheless, McNary-Haugen was the embryonic precursor to the idea of withholding supply at harvest to cause prices to rise, and through a loan mechanism be sold later. It also represented a movement that was protectionist and inconsiderate of free trade. It is no wonder then that in his book *Agricultural Reform in the United States* (1929), Black examined supply management and tariff-based allotments for selling commodities into domestic and export markets. These ideas or ideals paved the way for the Agricultural Marketing Act of 1929, and with much modification, the Hope-Norbeck Bill which laid out, in part, the terms of the Agricultural Adjustment Act of 1933.

Black then almost immediately went to work on research to investigate the Agricultural Adjustment Administration (AAA). With Edwin G. Nourse and Joseph S. Davis, he published a treatise in 1937 that was sympathetic to the AAA in general, but perhaps not to the point of calling it a success. However, this also brought him into contact with milk marketing, and using knowledge garnered through his work in index numbers, Black was the principal architect of the pricing formula for the Boston Milk Market (Galbraith, 1959).

As the agricultural economy languished into the depression years, differences in opinion as to how to deal with the farm problem arose. In Galbraith's memoirs

(1981; see also Parker, 2005), he characterizes these times as a feud between the "progressive" ideas of Black and the "retarded" ideas of G. F. Warren. Black, whose primary concern at the time was supply and production, saw the problem of low prices as one of overproduction. Hence, by managing supply through acreage allotments and adjustments, supply could be reduced, thereby raising prices. Warren, on the other hand, viewed the problem in terms of the financial markets.

These differing philosophies would, of course, lead to different solutions under the New Deal, with Warren and his acolytes favoring monetary reform in response to the tightening of credit, and Black and his acolytes favoring production reform (see Paarlberg, 1983). His discourse with Warren was probably not discomfited, for it seems over time that Black followed Warren's research as much as Warren followed Black's.

At any rate, both sides won favor with President Roosevelt—with Warren's side taking the lead on credit reform; with R. G. Tugwell, W. I. Myers, and W. L. Wilson the formation of the Farm Credit Administration (see Kirkendall, 1959); and J. D. Black, A. G. Black, and others the formation of the AAA.

Positivism versus Normative Economics

Black's standing of eminence placed him not only years ahead in terms of ideas but also as the premiere target for the earlier debate between normative and positivist aspects of agricultural economics research. In 1963, Glenn Johnson noted that it was Black who took up the cause for more economics in agricultural economics. While this is undoubtedly true, it was probably Schultz who propelled it. The call to normative economics was embraced by most except apparently those in farm management, as suggested by Schultz. Nonetheless, the 1930s and 1940s became formative in defining the direction and scope of agricultural economics and farm policy. Not only did Black's views of production influence the AAA (see Wilcox, 1952), but they also stretched into the burgeoning fields of conservation preservation and resource economics.

In attacking the positivist views of Black (and later E. O. Heady), Kenneth Parsons wrote:

> *The term 'Normative' . . . has unfortunately tended to become an opprobrious epithet reserved in certain circles for inaccurate supply estimates while accurate estimates are labeled 'predictive' or 'positive.' This unfortunate distinction arises from the desire of positivists to avoid purpose or ends as being animistic, teleological and, hence, non-scientific . . .* (1958, pp. 295–296, cf. Johnson, 1963).

For his part, Black writes in his 1953 *Introduction to Economics for Agriculture* (p. 120):

> *. . . when the economics of agricultural production is reduced to terms of the individual farm, it becomes what is ordinarily known as Farm Management. Any text book in real Farm Management is a treatise on the economics of production of the individual farm.*

In the end, both positivist and normative strands found an uneasy truce, with the theoreticians searching the annals of extension reports and farm surveys to provide input for, and/or evidence of, the normative models.

More realistically, Black was seeking a fair balance between theory and application, especially when it concerned issues of agricultural finance and farm management. This is evident as early as 1922 in his comment on the "Objectives in Agricultural Cost Accounting," where he struggles with the issue of imputed labor costs in enterprise budgets and offers up the solution of a regression equation to predict the physical relationship between inputs and crop yields, and from there use diminishing marginal productivity and expected output price to determine the imputed cost as the value of the marginal product.

This application of theory, while normative in scope, was clearly discussed in the context of a positivist outcome. It can also be seen in his 1940 rejoinder to T. W. Schultz's criticism of input-output analyses and quest for a purer form of economics, such as Kaldor and Hicks, where it becomes sentimentally clear that whatever normative tool the agricultural economist must use it must go no further than a means to an end, and the end point in Black's view was always a positive outcome [see Gardner (2006) for more on Schultz].

In fact, Black was somewhat dismissive of Schultz's view of the firm and was resistant to the use of concepts outside of agriculture:

> *Dr. Schultz's presentation would have been more understandable if he had tried to translate the words of Kaldor, Hicks et al., into the simple language of budget analysis in relation to anticipated changes in prices, costs, and technology. But then would there have been much of anything to say?* (Black, 1940, p. 577).

And later in this same publication, Black notes:

> *The writer [Black] regrets to state that he has found little enlightenment to such an end in the contributions of Kaldor, Hicks et al., to which Dr. Schultz makes generous reference. Economists working in the field of agriculture have long been accustomed to analysis in terms of the firm (the farm); and except for differences in language, have in one place or another, in large part if not wholly, covered the ground ploughed by the recent theorists of the 'firm.' It would not be surprising if some professor in our schools of business were to write an even better theory of the firm than Kaldor or Hicks* (Black, 1940, p. 580).

It is perhaps history's irony that Schultz became the one and only agricultural economist to win the Nobel Prize in economics. But, as Gardner (2006) points out, this was not for his work on U.S. agricultural policy, but his work on development economics and human capital. Nonetheless, Black was making the case that the agricultural economists had come to the same conclusions as Hicks et al. through the very means (cost studies and input-output analyses) that Schultz was criticizing.

In a further expression of this view, Black wrote about "unified farm management plans" in 1949. This paper, which is clearly a precursor to later linear programming applications in farm management, discussed the notion of an optimum which may not provide the maximum of many factors, such as soil conservation, but only achieve a single goal—net returns. Black had been applying optimum farm plans since at least 1937. The notion of a unified farm plan includes the efficient allocation of fertilizer and other variable inputs among competing management practices including tillage practices and crop rotations, labor availability, liquidity, and credit. The concept of a constrained optimum is represented by the additional requirement of feasibility, and the income inputs are based on future expectations rather than current income. The types of analyses described by Black relied heavily on input-output analysis, and he illustrated through such an approach how to circumvent the general criticisms of Schultz and introduce, for example, diminishing returns, credit, and expectations.

Agricultural Finance and Credit

Black's ideas on agricultural finance were quite different from those of G. F. Warren or W. I. Myers. He was perhaps in the minority of agricultural economists who supported public intervention. This, as discussed above, was reflected in his ideology regarding the AAA and, in the 1940s, extended to his thoughts on the role of public institutions and agricultural finance. Black always had an interest in farm finance and credit, but until about

1930 this interest was imbedded in his studies on management and production.

His first publication was an article on "Agricultural Credit" in the *Encyclopedia of Social Sciences* in 1930 (see Benedict, 1959). Around that time he also obtained a grant to study agricultural credit. Working with J. K. Galbraith, Black undertook the first critical assessment of the Production Credit Associations as enacted by the Production Credit Act of 1933, comparing the structure, function, and pricing of Production Credit Associations in relation to commercial lenders. Throughout the 1930s Black's overriding agenda was occupied with the Agricultural Adjustment Administration and other research, leaving little time for direct work on farm credit—which is likely why his collaboration with Galbraith was relatively passive.

A related exception was his sympathetic work with R. H. Allen on land tenure in 1937, examining the decline in farm ownership due to increased sharecropping activities (the tenancy problem) or indebtedness (the equity problem) over the previous 50 years, and including the impact on (primarily cotton) tenancy from mechanization, relief work, and the AAA.

Black also noted an interesting correlation between rising indebtedness and tenure. Indebtedness in this context was measured relative to market values of land which rise during booms and decline during busts. Foreclosures on heavily mortgaged farms gave rise to increased tenant status. Again in a sympathetic tone, he outlined the discrepancy in ownership between white farmers and African Americans and lamented the conditions of poverty faced by southern tenant farmers. Black noted that across the United States between 1926 and 1929, 8.7% of farms faced forced sales, and this number increased to 23.6% between 1930 and 1936. In the 10 years prior, between 1926 and 1936, 32.3%, nearly one-third of all farms, turned over through forced sale conditions. The heaviest occurrences were in the Great Plains and the South, with turnover reaching as high as 43% in the Northern Plains.

Still, Black's attitude toward credit during the depression was prudential and conservative, as were many of the writings on farm credit in the 1930s. Credit was to be secure enough to ensure a steady flow of funds into the Land Banks. But in the 1940s this attitude changed. By then, Black was thinking more in terms of credit as an input into the production process, with its absence being a significant constraint to agricultural productivity. In 1945 he writes:

> *Since the First World War and especially the great depression, the role of credit in agriculture has evolved so rapidly that credit agencies and credit legislation have not kept up with it. There is an even greater lag in the prevailing ideas about the function of credit in agriculture* (1945, p. 591).

Indeed, prior to 1945 (and even later), farm credit was viewed not so much as a liability in the accounting sense but a liability in the context of survival. A loan was made not on its value to production and investment, but on the resale value of the farm. Black argued for the first time that lending should be tied to production and planning rather than assets and security. In other words, what cash flows could be leveraged by investment? And is the cash flow sufficient to repay the debt in full? Black believed that farm management, production, and agricultural finance were interconnected and that farm planning for the purpose of obtaining credit should be part of a publicly subsidized activity.

In fact, Black would make the case for the provision of public funding in agriculture:

> *It seems to be in the nature of agricultural credit that competition among private lenders does not bring about improvements needed, or brings them about too slowly* (1945, p. 595).

Black argued that while public credit may crowd out private lending in the short run, this would dissipate in the longer run as private markets recognize the advantage to lending in a farm-planned agricultural economy.

But perhaps the biggest departure was Black's recommendation that public credit be used to shore up farms which are beyond the reach and risk aversion of private lenders. Black's view on this subject was relative to other farm support policies of the time. Instead of providing a monetary subsidy such as those under the AAA, which was a direct and irrevocable expenditure, supporting credit with a reasonable chance of full repayment plus interest would go much further in assisting agriculture. Black was not only referring to limited resource agriculture but also to bailing troubled farmers out when it comes to adversities such as severe agricultural depressions, droughts, and other disasters. Disaster assistance would diminish as credit reserves became more abundant in agriculture, agricultural loans were adapted to fit the needs of agriculture, and new insurance policies came to maturity.

A more pronounced role for agricultural credit is the provision of loans to deserving limited-resource farmers on small lots with large mortgages who have not obtained sufficient economies of scale to achieve the benefits from the loans, let alone the surety of repaying them. Because of this risk, they could not obtain loans to increase the size of the farm, and without increasing farm size they could not achieve economies of size—a dynamic Black referred to as a "vicious circle."

Black's recommendation was that public credit should be provided as farm enlargement loans to offer farmers the opportunity to achieve such economies and a better balance of risk. At the time, the Federal Land Banks required a 50% downpayment on land and 20% on buildings, which did not provide the opportunity for significant expansion. The maximum loan amount was 75% if the land bank loan was combined with the so-called commissioner's loan, but Black was calling for a mortgage even higher than this.

Black also advocated credit facilities for improvement loans by making the case that existing land improvements such as drainage, irrigation, pasture improvements, land clearing and terracing, and constructing or improving outbuildings could increase profitability and output by 25% or more. Yet loans of this type were simply not available at that time, although the cash flow from such improvements would no doubt be sufficient to cover the loan payments.

Further, Black called for credit to improve small woodlands and farm buildings. On the latter issue, his concern was more than pragmatic. The persistent downturn in the agricultural economy between the First World War and the great depression saw rising costs of labor and lower commodity prices and revenues. Homes and outbuildings were neglected on many farms as a matter of home economy, but a robust post-war agricultural economy would need massive infusions of cash to repair the buildings and homesteads.

Black also made the case for Tenant-Purchase loans whereby returning veterans should be provided special consideration, and the government should underwrite some of the risk of land speculation. On this topic he argued for prudence to let wartime land price increases settle down, and an interesting but rather impractical strategy of writing down a mortgage after 10 years if land prices had declined. Of Farm Services Agency (FSA) five-year rehabilitation loans targeted to low-income farm households, Black recommended increased extension to FSA recipients even at a possible net loss to the government, and extensions of the loans beyond five years so that improvements and benefits could be matched to repayment. For many thousands of substandard farm families he did not see a "collections-only" policy as supporting the greater good and public purpose, but rather FSA-type programs should be integrated with other programs to ensure immediate economic needs were met, and options for future prosperity left open.

Such notions in 1945 were a far cry from the overriding philosophy of the Farm Credit Administration (FCA), which was to support only farms that were managed well and viable. The reason for this change of heart may be related to the status of the FCA, which in 1939 was removed as an independent agency (as envisioned by W. I. Myers) to an agency under the Department of Agriculture. Massive subsidies under the AAA and other programs were pouring into agriculture, and Black saw that by investing in targeted credit policies the same ends could be achieved but through less costly means.

Black's perspective may also have been influenced by the fact that his friend A. G. Black, whom he knew from the University of Minnesota and who worked with him at the AAA in the early days of the New Deal, was the Governor of the FCA between 1940 and mid-1944—a time when J. D. Black would most surely have been writing or thinking about agricultural credit policy. Between 1939 and 1944, the FCA had become an agency of policy, with the goal of a self-sustaining, owner-operated farm financial institution being relegated to the back burner. In fact, it was rumored that the reason A. G. Black's predecessor F. F. Hill resigned in 1940 was that Secretary Wallace had asked the Farm Credit System to participate in distributing FSA rehabilitation loans which could have incurred losses for system stockholders at a time when many national farm loan associations had already incurred losses (Stokes, 1973).

The potential remedy facing A. G. Black was the Wheeler-Jones Bill which not only would have required that capital stock of the loan associations be returned to members at par, but essentially the entire cooperative structure of the Farm Credit System be dismantled. Wheeler-Jones was rejected but shortly after A. G. Black left the post in 1944, another attempt was made to dismantle the Production Credit Associations with a committee comprised of five professors concluding that the capital stock concept in Production Credit Associations was unrealistic and unsustainable (Stokes, 1973).

In 1945, when J. D. Black was writing on agricultural credit policy, the System was in flux. Using the Farm Credit System as an agent of policy would probably not have been well received by the System, but surely J. D. Black was looking at new credit policies as viable instruments that could remove many of the nonrecoverable expenditures of the AAA while increasing overall efficiency in agriculture.

Black, as noted above, was searching for practical solutions to credit issues that were efficient and equitable as a policy response. On long-term debt, he was pushing for variable-payment mortgages in which farmers would pay less principal in bad years and more in good years. Galbraith had elucidated these ideas with R. M. Macy and W. Malenbaum in 1937, and Black also brought up the idea in his study on tenancy (Black and Allen, 1937), and 10 years later when he was writing on the future role of government in the farm lending field (Black, 1947). A sequence of low years would prolong the life of the mortgage and a sequence of good years would shorten it. Such a mortgage would reduce the variability in cash flow using excess liquidity in good years and shoring up liquidity in bad years. This system would require less intervention from the AAA and would naturally cover a greater number of crops and fixed farm types. The impracticable aspect was that lenders would be receiving a random stream of payments which would limit long-term lending strategies.

Intermediate credit posed a different problem. Black noted that in any depression, especially one following a boom, credit from commercial sources would dry up rapidly. Farmers would then use up any working capital to repay existing credit, with little opportunity to refurbish liquidity for production. Often, productive assets had to be sold. And frequently this was because there was no liquidity matching between loan duration and life of capital. An asset with a three- to five-year life was purchased using a loan with a one-year term, creating a virtual impossibility for repayment in most circumstances! Even Production Credit Associations were requiring repayment schedules that did not match the real returns from leveraged capital. Black was calling for flexibility in production and intermediate credit both from within the system and outside the system. Black was making the same arguments as late as 1955, and liquidity matching is currently a major tenet of agricultural finance practices.

The final view on agricultural credit was related to servicing. By "servicing," Black meant the actual management of the loan by the lender. Servicing moderated all of his views, and it was within the context of servicing that his proposals were set. Indeed, Black recommended that each county have a credit committee comprised of the county agent, lenders, and other experts. The committee would assist the farmer in putting together a management plan, and the management plan would be used to determine credit allowances and limits. In 1947, Black extended this idea noting that the policies of the day focused on "action"—i.e., increasing the amount and number of loans to farmers, with "education" and "research" lagging. Education and research in his context were directed toward agricultural finance and the management of cash flow. Here, Black argued that the problem of farm credit could easily be overcome if lenders, and more specifically public lenders, started first with education and research and then subsequently took action. Production and farm management were not dispensable when it came to managing credit and credit relationships.

The Legacy of J.D. Black

In the introductions to each of the sections in *Economics for Agriculture: Selected Writings of John D. Black* (edited by Cavin, 1959), respective authors would continually write statements such as "this was the last paper he wrote on the subject," or "he did not write on this topic for another 10 years," and so on. These were curiôus observations, but when Black's career is examined at as a whole, some clarity emerges. Black would tackle the problems of the day in earnest. There were to him two classes of problems, those requiring immediate attention due to the current state of the agricultural economy (the positivist side of Black) and a search for practical solutions, and those of a more theoretical nature (the normative side of Black). Thus, while he was writing "Elasticity of Supply of Farm Products" in 1924 while still at the University of Minnesota, he was trying to encourage the adoption of correlation analysis as had recently been used by Holbrook Working to investigate the impact of supply management in the context of marketing boards and cooperatives.

Reading J. D. Black's work is rather heady by today's standards only because it lacks the mathematical rigor that we are now accustomed to. But in the present day when we assess a formula such as

$$\pi = P(Y)Y(x) - C(Y)$$

or

$$\frac{\partial \pi}{\partial Y} = P\frac{\partial Y}{\partial x} + Y\frac{\partial P}{\partial Y} - \frac{\partial C}{\partial Y},$$

we recognize it almost immediately as a production relationship and take it for granted. But what we understand today, largely popularized by E. O. Heady in the 1950s, has its genesis in the foundation principles of J. D. Black in the 1920s. And when we consider

$$Y = a + bx - cx^2 + e,$$

a basic regression for a curvilinear relationship exhibiting diminishing marginal returns and, on extension, multiple complementary and supplementary inputs, we owe much to Black's initial and forceful faith in correlation and regression analyses to investigate input-output relationships in the mid- to late 1920s and into the 1930s.

Likewise, when we observe a mathematical statement such as

$$\underset{x}{\text{Max}}\; C'X$$
$$\text{s.t.: } AX \le B,\; X \ge 0$$

to describe a linear programming model for determining an optimum farm plan, much of the credit is given to the simplex algorithm and the early masters of operations research. But to its present form and construction we owe much to J. D. Black's persistent view of farm management as a representation of incremental tradeoffs among budgeted alternatives and his focus on optimality that provided the simulacrum that made the transition from applications of military strategy to applications in farm management so appealing.

And when we consider the conventional bid price equation

$$V = \frac{A(1+g)}{r-g},$$

we understand that A denotes the incremental cash flows from production, g its growth rate, and r the discount rate, but we owe much of what we take for granted to the early specifications of land economics as defined by J. D. Black and even an early plea to moderate shady real estate practices (Black, 1925b).

There is of course more, much more than can be told in a limited-space biography. (For example, throughout the war years and into retirement, Black became increasingly involved in issues of price parity, food adequacy, and farm policy.) Yet it is worth ending on a note that illustrates the perspicacity and propitious tendency of J. D. Black to hold insights and cultivate ideas on matters known and understood by him, but not recognized as being important for years to come.

In 1925, while considering the role of public agencies in the readjustment of farms to the post-war recession, he writes:

> *. . . but agriculture does not so readjust itself. It does not partly because it cannot, and partly because for no reason at all, except that it is agriculture. The reasons why readjustments cannot be made quickly are so obvious that only a few need to be mentioned—for example fixed investments required in buildings, equipment, and livestock; well established crop rotations; time required to learn new enterprises and new methods; time required to develop new marketing facilities. Probably more important than all these in preventing readjustments, however, is the psychology of the farmer himself—his apathy in some cases, his conceit in other cases, his refractoriness in others, only his enmeshment of habits, customs, and traditions in other cases. . . . The effect of this is to introduce a considerable lag between the point of incidence of any such disturbing influence and the time of response to it. The response time varies greatly according to the system of farming involved . . . the size of the disturbance . . .* (Black, 1925a, pp. 165–166).

The problem of adjustment is as pertinent to the present agricultural economy as it was to that of the 1920s, but in the present we refer to the fixities Black writes of in terms of irreversible investment and the disturbances as the underlying risks, an increase of which will result in a "real option" to postpone investment and delay adjustment. While the itemization may not be exact in meaning to today's views of investment under uncertainty, its context and significance are most certainly prescient.

J. D. Black died of a heart attack in January 1960, just months after *Economics for Agriculture* was published in his honor. His official retirement from Harvard University was in 1954, but he continued as the Henry Lee Emeritus Professor. In a 35-year retrospective of the *Journal of Farm Economics*, Arnold and Barlowe (1954) counted J. D. Black as the *Journal*'s top contributor with a total of 53 contributions between 1919 and 1955, and the lead contributor between 1929 and 1945 (total = 33). Between 1946 and 1955, with 15 contributions, he topped T. W. Schultz by 1, and was himself topped only by E. O. Heady (by 1).

To place this prolificacy in context, of 22 contributions by the University of Minnesota between 1919 and 1928, five belonged to Black; of the 82 contributions from Harvard between 1929 and 1955, Black contributed 58%; and of the 19 universities that had 25 or more contributions over the same period, Black alone contributed more to the *Journal of Farm Economics* than 11 of them including Kansas State with a total of 52 and Purdue and Stanford with totals of 50 each.

Three years before his death, Black was one of the original inaugurates into the Fellowship of the American Farm Economics Association (now AAEA), along with such contemporaries as T. N. Carver, E. G. Nourse, T. W. Schultz, H. C. Taylor, F. V. Waugh, and M. L. Wilson. In Black's obituary published in the May 1960 issue of the *Journal of Farm Economics*, J. P. Cavin and R. L. Mighell wrote:

> *For a good many decades to come, and perhaps as long as agricultural economics is taught with decent attention to its origins, students will be hearing the name of John D. Black* (p. 224).

On this we refer back to Heady and Dillon's (1961) query discussed previously, but spattered throughout the literature are gems of eminence. For example, in the 1969 volume on *Readings in the Economics of Agriculture* for the American Economics Association, editors Karl A. Fox and D. Gale Johnson are almost apologetic to Black for not including any of his writings in the volume. In 1950, D. Gale Johnson, writing on the nature of supply functions, states that the best published discussion of the responsiveness of agricultural output to price changes was by Galbraith and Black published 12 years earlier. Wells (1953), noting Black's book on production is actually a textbook, states, "yet he has his usual say about a number of things."

On Black's Harvard days, Mason and Lamont (1982) state that although Harvard was not an obvious location for the flowering of farm economics, Black during his lifetime made it one of the leading centers in the country with (as discussed earlier) graduate students flocking to Cambridge to work with him. He was, they say, "a terrible teacher," but was tireless with students, bent the rules to get them through exams, and took a keen interest in their careers.

For example, Ray Goldberg, the George M. Moffett Professor of Agriculture and Business Emeritus at the Harvard Business School, credits much of his success to the encouragement by Black that led him to doctoral studies at the University of Minnesota. John Kenneth Galbraith, arriving in Cambridge from Berkeley in the early 1930s, lionizes Black in his memoirs and gives Black much of the credit for his many successes (Galbraith, 1981; Parker, 2005). Vernon Carstensen (1960) identifies Black as the main instigator of the battle between positivist and normative thought in agricultural economics—a battle, albeit simmering for the most part, that still wages to this day. B. F. Stanton (1978) laments the passing of the pioneers in agricultural economics, noting that J. D. Black's seminal *Introduction to Production Economics* in 1926 placed the whole concept of capacity in production into perspective.

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Factors Influencing Borrowers' Preferences for Lenders

Travis A. Farley and Paul N. Ellinger

Abstract

Data from a survey of Midwest producers are used to examine the credit-source decisions of farm borrowers. The lender attributes preferred by producers are identified in terms of their importance in selecting credit providers. The influence of farm business information on farmers' interest rate sensitivity and loyalty is investigated. Regression results indicate that patrons of the Farm Credit System are more likely to be highly price-sensitive. Furthermore, the likelihood for strong borrower loyalty is found to be higher for smaller, less leveraged, and more tenured farms and by those who source financing from bank institutions.

Key words: binomial logit, interest rate sensitivity, lender attributes, lender-borrower relationships

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Changes in the agricultural and financial sectors continue to impact the delivery of financial services and products and alter the roles that agricultural lenders play in the market. Increased competition among lenders acts as a major catalyst for change in the agricultural credit market. The Farm Credit System's (FCS's) Horizons project exemplifies the nature of the competitive landscape. In an effort to better understand the financial needs of agricultural producers, the FCS undertook this research initiative to identify factors driving change in U.S. production agriculture. Although competitive pressure is not a new characteristic of the financial industry, certain aspects of the evolving market structure represent a recent degree of heightened competition. Competitive forces are not only changing, but coming from a wider range of market participants as the dominance of traditional lenders—domestic commercial banks and the FCS—is being challenged through various dimensions.

The emergence of alternative sources of agricultural credit pressures existing lenders to be more responsive to the needs of borrowers. Captive finance companies continue to offer innovative financing alternatives, while the U.S. market entry of international financial institutions is reshaping the competitive arena. One such multinational bank, Rabobank, exemplifies the increase in transnational lending in U.S. agriculture. This Dutch finance company has made substantial investments in the U.S. farm credit sector through purchases of banks, agricultural mortgage firms, and crop input lenders. New credit suppliers to the farm market, as well as traditional ones, need to understand the attributes of the lender-borrower relationship highly valued by different borrower segments to compete successfully in the evolving credit marketplace.

In light of the changes occurring in agricultural production and finance, it is important for lenders to understand the factors that influence producers' decisions in selecting sources of farm credit. Lending relationships can affect profitability over time through higher costs or enhanced customer service and loyalty. Hallowell (1996) uses data from 12,000 retail-banking customers to illustrate that customer satisfaction, customer loyalty, and profitability are related to one another. Using survey data on agricultural loans and simulation models, Gunderson, Gloy, and LaDue (2006) estimate the value of longer-term lending relationships. Their results suggest that after accounting for risk, large loan relationships generate more lifetime value, but smaller loans tend to add more value per dollar of loan.

As farmers' demographics change, so may their preferences for lender attributes. Some customer segments are more likely to be interest-rate sensitive, while other segments place considerable value on the lender-borrower relationship. Identifying and responding to borrower expectations and offering the proper product mix are important to lenders maximizing profits.

Prior studies on producers' preferences for lender attributes have focused primarily on evaluating the importance farmers place on certain factors associated with selecting a credit source. Bard, Craig, and Boehlje (2002) use attribute ratings and conjoint analysis to ascertain preferred lender characteristics. Their results indicate that the time-to-loan decision, amount of loan provided, lender's interest rate, and lender's specialization in agriculture are key attributes farmers prefer in a credit provider. This conjoint analysis confirmed that producers are not willing to trade a higher interest rate for some other lender qualities. Similar attribute rating research is regularly published in trade journals, such as *Ag Lender* and *American Banker*.

Theories on lending relationships generally conclude that establishing a relationship is valuable to small firms. Stiglitz and Weiss (1981) contend that banks may fail to allocate loans efficiently because of information problems, and they claim rationing is a likely outcome because of the difficulty in obtaining adequate information. This lack of sufficient information gives rise to adverse selection and moral hazard. As noted by Stiglitz and Weiss, banks cannot be adequately compensated by charging higher interest rates, and thus credit rationing occurs. Lending relationships have been viewed as a mechanism to reduce information problems in lending markets and potentially decrease credit rationing.

Empirical research suggests small businesses benefit from a strong lender-borrower relationship in both credit availability and credit terms. Petersen and Rajan (1994) find that a small firm's access to financing increases as its relationship with the credit institution matures. However, they do not observe a significant association between the duration of the lender-borrower relationship and the pricing of credit. Specifically, through close and continued interaction, a firm may provide a lender with sufficient information that ultimately leads to lower interest costs, an increase in the availability of credit, and a reduction in credit rationing.

Berger and Udell (1995) investigate only lines of credit to analyze the link between loan rates and collateral and the length of the banking relationship. They conclude that small firms with longer credit relationships pay less for borrowing, except for very small businesses (firms with less than $500,000 in total assets). Moreover, borrowers with longer banking relationships are less likely to pledge collateral to secure loans.

Cole (1998) explores how a preexisting relationship between a small business and a potential lender influences the likelihood of the business receiving credit. Based on Cole's findings, interacting with a lender through the use of savings accounts and financial management services improves the firm's chance of securing financing from the lending institution.

The empirical evidence suggests small businesses using debt capital have incentives to develop a relationship with a lender. Furthermore, the literature argues that these incentives increase as the lender-borrower relationship progresses, thereby explaining the motivation for the relationship to evolve into strong borrower loyalty. Our study extends the analysis to farm businesses in an effort to investigate if the relationship plays a significant role in producers' selection of a lending institution.

Most of the statistically based research on relationships in agricultural lending explores how these interactions influence customer loyalty. Barry, Ellinger, and Moss (1997) collected data from a survey of Midwestern agricultural banks. Their study employs an ordered probit method to regress each respondent's loyalty rating for agricultural borrowers against three groups of predictor variables comprised of different lender attributes. According to their findings, lenders consider the relationship with the loan officer to be the most important factor in determining borrower loyalty. Furthermore, relationship-intensive financing is found to be essential to a bank's ability to secure business volume. Ninety-one percent of respondent banks rated long-term service from the same loan officer as highly important to maintaining a competitive position in the farm lending market. Using the lender-borrower relationship as a proxy for customer loyalty, their investigation can be extended by identifying loyal farm borrowers and examining their farm business information.

This study provides an analysis of the attributes that factor into producers' credit-source decisions. In an effort to build upon previous research, we examine the statistical influence of selected farm business and financing characteristics in identifying which producers are likely to be highly price sensitive and which ones may exhibit strong loyalty to a single lender.

The primary objective of this research is to assess the information used by farmers in selecting agricultural lenders. Specific objectives are to: (*a*) compare mean lender attribute importance ratings among producers with different credit preferences, (*b*) identify farmers who are highly interest-rate sensitive and those who exhibit strong degrees of borrower loyalty, and (*c*) determine how levels of farm business and financing characteristics influence borrower price sensitivity and loyalty.

Data and Methods

Data were generated through a mail survey of producers in Illinois, Indiana, and Iowa. Respondents were randomly selected from the Progressive Insight database, a market research database of 1.2 million farm operators. This list is maintained by *Progressive Farmer*, a company that interacts extensively with agricultural producers through farm magazines, surveys, and other channels. The database allows for segmentation by demographic criteria. Accordingly, the criteria established for this study required that the farmer operate more than 300 acres and reside in Illinois, Indiana, or Iowa.

Several previous surveys seeking similar information and a pilot study administered through a community bank contributed to survey development. Items in the survey investigate farm business information, financing characteristics, incidence of changing lending institutions, and the importance of selected lender attributes. (A copy of the survey instrument is available from the authors upon request.) Surveys were distributed whereby 1,500 Illinois farmers, 750 Indiana farmers, and 750 Iowa farmers received the questionnaire.

A total of 538 usable surveys were returned, yielding an effective response rate of 18%.[1]

Variables analyzed include age, education, farm size, tenure, leverage, off-farm income, and sources of credit. The anticipated influences of these measures on the price sensitivity and loyalty of producers are explored in the following discussion.

Age and Education[2]

Little empirical evidence exists regarding the price sensitivity of banking services by age (Amel and Starr-McCluer, 2001). Older producers are hypothesized to have built a relationship with a specific debt capital provider and may have experienced the benefits of the lender-borrower relationship through periods of poor and strong economic times. Furthermore, the credit relationship is likely to strengthen as farmers age, resulting in less sensitivity to marginal changes in debt costs. Therefore, agricultural borrowers greater in age are anticipated to be less interest-rate sensitive.

The expected relationship of price sensitivity and educational attainment was not assigned. A well-educated borrower is likely to be better informed about loan terms. A positive relationship may suggest a better understanding of the farm's financial position and how lower interest rates relate to financial performance. However, a negative relationship could imply a better understanding of the importance of establishing advisory teams of professionals and how knowledge of agriculture in general and knowledge of the borrower's specific business relate to the long-run success of the business.

Farm Size[3]

Acres Farmed serves as a proxy for the size of the farm business. Managers of larger farm operations are hypothesized to be more price sensitive and demonstrate less borrower loyalty. Larger commercial farms tend to carry greater amounts of debt and are generally more highly leveraged (Ellinger et al., 2005; U.S. Department of Agriculture, 2006). Hence, producers with larger farms may be more price sensitive. With larger outstanding loan balances, and therefore greater interest expenses, these producers are expected to be more concerned about marginal changes in interest rates and less committed to a specific financial source. Moreover, lenders will likely compete more aggressively for larger borrowers, and consequently provide more opportunities for these borrowers to switch lenders.

Farmland Lease Ratio

The *Farmland Lease Ratio* is the percentage of acres operated under a lease arrangement. The anticipated relationships between this measure and both price sensitivity and relationship strength are ambiguous. On the one hand, producers leasing a larger percentage of acres farmed may be less responsive to marginal changes in debt costs and more inclined to build loyalty with a single lender. Greater reliance on leased farmland may reflect a weaker financial position, thereby placing more importance on the operator's creditworthiness in a lender's decision to extend debt capital. As a result, farmers leasing a high proportion of acres may value a solid credit relationship by exhibiting strong customer loyalty. In contrast, profit margins on leased acres are often lower than owned acres (Schnitkey and Lattz, 2006). Hence,

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[1] Using a standard power test, the authors are confident within 4.22% that the sample of respondents accurately reflects the study population.

[2] The age variable is excluded from the borrower loyalty analysis because respondent age is used to build the loyalty-dependent variable.

[3] This study explored the use of annual farm sales as a measure of farm size. Results from incorporating *Acres Farmed* and *Annual Farm Sales* separately into the regression equations are not significantly different. Furthermore, *Acres Farmed* yields stronger levels of significance.

farmers may strive to acquire the lowest price credit available to maintain profit margins or to allow them to increase cash rent bid prices.

Leverage

Leverage is measured by the debt-to-asset ratio. The expected relationships between leverage and both price sensitivity and relationship strength are also ambiguous. Farm operators with higher levels of debt compared to assets may exhibit strong borrower loyalty. Highly leveraged producers may have access to a limited number of lenders willing to serve their credit needs, thereby reducing their opportunities to secure lower-cost financing. This situation may encourage borrowers to build a strong credit relationship with a single supplier to ensure a dependable source of capital. On the other hand, higher degrees of leverage may result in credit rationing through price and nonprice responses. These borrowers may not exhibit strong lender loyalty and attempt to acquire the lowest cost of credit.

Off-Farm Income

Higher levels of *Off-Farm Income* contribute to the financial stability of the farm business. Thus, producers with greater earnings from nonfarm sources (by the farm operator and/or spouse) may choose to be more price conscious when selecting a credit provider and less loyal to a single financing source. Moreover, nonfarm credit sources and financial services may be more readily available to businesses with higher levels of off-farm income, also leading to less loyalty to a single financing source.

Credit Sources

Sources of agricultural operating credit are represented by two primary categories of lenders: the FCS and bank institutions. Respondents are asked to indicate the use of one or both lenders in financing operating activities during a three-year period. Consequently, these two credit sources are not mutually exclusive. The directions of the effect of credit sources on price sensitivity and customer loyalty are ambiguous.

The mean importance scores of lender attributes are compared across two measures of borrower price sensitivity and loyalty using a multiple comparison procedure. The Tukey-Kramer means separation test is employed to detect significant differences between individual treatment means.[4]

The examination of survey data is expanded through logit analysis by utilizing regression models to investigate the characteristics of price sensitivity and loyalty of agricultural borrowers. The econometric techniques explore how selected farm business and financing characteristics of survey respondents explain the outcomes of two dichotomous response variables: (*a*) high versus not high borrower price sensitivity, and (*b*) strong versus not strong borrower loyalty.

Because these decisions are reflected by discrete outcomes, a binary logit model is employed to determine the significance of relationships. The results of the logit analysis indicate the probability of association between the independent variables and the dependent variables. Binomial logistic regression describes the relationships between a dichotomous dependent variable and a set of discrete explanatory measures (Greene, 1993).

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[4] The Tukey-Kramer test is applicable for pairwise comparisons of unequal sample sizes. Two means are considered significantly different if

$$\frac{|\bar{y}_i - \bar{y}_j|}{s\sqrt{\dfrac{(1/n_i + 1/n_j)}{2}}} > q(\alpha;\, k,\, \upsilon),$$

where $\bar{y}_i$ and $\bar{y}_j$ are the respective means for groups i and j, s is the root mean squared error (also known as the pooled standard deviation), n_i and n_j are the number of observations in the ith and jth groups, and $q(\alpha;\, k,\, \upsilon)$ is the critical value for the studentized distribution of k normally distributed variables with υ degrees of freedom at the α significance level.

The *Price Sensitivity* dependent variable is mapped using respondents' reasons to switch primary lending institutions. Respondents were asked to rate the importance of 13 different incentives for changing credit providers. The influence of a 50-basis-point interest rate difference between lenders is used to define price sensitivity for the price sensitivity logit model. The dependent *Price Sensitivity* variable for an interest rate difference of 50 basis points has a value of 1 (highly sensitive) for importance ratings of 4 and 5, and a value of 0 (not highly sensitive) for importance ratings of 1, 2, and 3.[5,6]

In the borrower loyalty model, loyalty is a function of three respondent characteristics: age, years with current primary lender, and borrowing life. Borrowing life is defined as the maximum number of years a producer could have been borrowing. Responding farmers are classified as highly loyal if they satisfy at least one of three judgmentally determined criteria: (*a*) the farmer is at least 26 years old and has spent five years or more with the current lender, (*b*) the farmer is 40 years of age or older and has spent 10 years or more with the current lender, or (*c*) at least half of the farmer's borrowing life has been spent with the current lender.

Borrower Loyalty serves as a binary response variable by equating "strong loyalty" with 1 and "not strong loyalty" with 0. The loyalty measure relies primarily on the duration of the financial relationship with respect to borrower age. Akhavein, Goldberg, and White (2004) provide support for the length of the lender-borrower relationship serving as a proxy for the strength of the credit relationship. Furthermore, Moss, Barry, and Ellinger (1997), and Hanson, Robison, and Siles (1996) conclude that the borrowers' relationship with a financial institution is a significant factor in building customer loyalty.[7]

This study considers price sensitivity and loyalty to not be mutually exclusive. A producer can rate both price and the lender-borrower relationship as important attributes when selecting a credit source. The statistical analyses examine the price sensitivity and strength of loyalty exhibited by all respondents using debt capital.

Results

Tables 1–4 convey the results from the evaluation of survey participants who demonstrate a high degree of price sensitivity and a strong level of customer loyalty. Because respondents in this research can fall into both categories—high price sensitivity and strong loyalty—a cross-tabulation indicating the joint distribution of the two dependent variables is reported in Table 1. Of these borrowers classified as highly price sensitive, 60% also fall under the strong loyalty label. Twenty-four percent of producers not considered to be highly price sensitive are also regarded as not demonstrating strong borrower loyalty. When examining respondents who are characterized as very loyal, 69% belong to the high price sensitivity group. Finally, of those farmers described as displaying less loyalty, 49% are also less sensitive to price.

Table 2 reports the frequency distribution of respondent demographic and farm business information categorized by "high" versus "not high" price sensitivity and "strong" versus "not strong" loyalty. Significantly different proportions between the two levels of price sensitivity and loyalty are denoted by superscript

[5] Importance ratings are based on a five-point Likert scale, where 1 = not important and 5 = very important.

[6] Other methods for gauging interest rate sensitivity were investigated, such as the importance of a 25-basis-point margin in considering switching lenders. The alternative measures were each separately incorporated as dependent variables in the price sensitivity model. However, the regression analyses produced no statistically significant differences in results among the different measures.

[7] The authors recognize that producers whose financial institution has merged could be loyal borrowers, but do not fall under the "strong loyalty" classification according to the variable definition.

Table 1. Price Sensitivity and Loyalty Cross-Tabulation (%)

	Price Sensitivity		Loyalty	
Description	**High**	**Not High**	**Strong**	**Not Strong**
Strong Loyalty	60	76	—	—
Not Strong Loyalty	40	24	—	—
High Price Sensitivity	—	—	69	51
Not High Price Sensitivity	—	—	31	49

Table 2. Respondent Characteristics by Price Sensitivity and Loyalty (%)

	Borrower Price Sensitivity		Borrower Loyalty	
Demographics	**High**	**Not High**	**Strong**	**Not Strong**
Age:				
< 35	4	4	3	6
36–45	18 ^{A}	25 ^{B}	17 ^{A}	27 ^{B}
46–55	41	38	40	37
56–65	24	22	27 ^{A}	18 ^{B}
> 65	13	11	14	12
Tillable Acres:				
< 500	13	13	13	15
500–1,500	51 ^{A}	59 ^{B}	56	51
1,501–2,500	25	20	23	21
2,501–5,000	8	6	7	9
> 5,000	3	2	1 ^{A}	5 ^{B}
Bank Use:				
Yes	72	77	76 ^{A}	68 ^{B}
No	28	23	24 ^{A}	32 ^{B}
FCS Use:				
Yes	37 ^{A}	28 ^{B}	32	34
No	63 ^{A}	72 ^{B}	68	66
Education:				
Less than high school	0	1	1	0
High school	24 ^{A}	34 ^{B}	32	26
Some college	23	22	22	21
2-year degree	16	12	12	17
4-year degree	29	30	29	28
Graduate degree	7	2	4	7
Farmland Lease Ratio:				
0.00–0.10	14	15	16	14
0.11–0.20	7	7	8	4
0.21–0.50	25	21	23	21
0.51–0.75	26	23	25	22
> 0.75	29	34	28 ^{A}	39 ^{B}
Leverage:				
0.01–0.10	32 ^{A}	23 ^{B}	29	28
0.11–0.40	48 ^{A}	59 ^{B}	54	48
0.41–0.70	18	15	15	18
> 0.70	2	3	1 ^{A}	5 ^{B}

(continued . . .)

Table 2. Continued

Demographics	Borrower Price Sensitivity: High	Borrower Price Sensitivity: Not High	Borrower Loyalty: Strong	Borrower Loyalty: Not Strong
Off-Farm Income:				
$0	18	18	19	18
< $25,000	37	40	40	36
$25,000–$50,000	24	28	25	24
$50,001–$75,000	14[A]	8[B]	11	14
> $75,000	8	5	6	8

Note: Sample proportions denoted by superscript alphabetical letters A and B within each dependent variable are significantly different ($p > 0.05$).

alphabetical letters A and B. Findings from these descriptive statistics are largely consistent across each classification for both dependent variables. The largest percentage of respondents is between 46 and 55 years of age. The majority of producers manage between 500 and 1,500 acres. A significantly greater portion of "not highly price-sensitive" farmers fall within this acreage bracket compared to the percentage of "highly price-sensitive" producers. A majority of respondents source financing from bank institutions, while a smaller proportion patronize the FCS.[8] Statistically proportional differences are identified between the two loyalty levels for the *Bank Use* variable and between the two price-sensitivity levels for the *FCS Use* variable.

The education level of responding producers is less consistent between each class within both dependent variables. Of the farmers who demonstrate high price sensitivity and low customer loyalty, the largest percentage have a four-year degree, while most of the highly loyal and less price-sensitive respondents have only a high school education. Across measures of interest rate sensitivity and loyalty, the largest percentage of survey participants lease more than 75% of total acres operated, exhibit a debt-to-asset ratio between 0.11 and 0.40, and earn less than $25,000 in annual off-farm income.

[8] The level of borrowing for the sample cannot be compared directly to market share data since the amount of borrowing from each lender was not obtained.

Table 3 reports the average importance scores for selected lender attributes. These attributes are listed in order of importance according to the average ratings from all survey respondents. Although differences in preference scores between each category are observed for each treatment variable, only two attributes exhibit significantly different mean ratings, according to the Tukey-Kramer means separation test. Highly price-sensitive respondents provide a statistically higher mean rating to the lender's interest rate compared to farmers less sensitive to financing costs. All other attributes have insignificantly different mean scores between the two classes. In the borrower loyalty variable analysis, the only lender characteristic with a statistically significant difference in ratings between the two groups is the lender's dependability as a source of credit. Respondents strongly committed to a single financial institution rate this attribute significantly higher in importance.

Results from the means tests support the validity of the methods used to build the treatment variables. One would expect highly price-sensitive respondents to assign a significantly higher average importance score to the *Interest Rate* attribute compared to their counterparts. Furthermore, as one would anticipate, borrowers with stronger customer loyalty place greater importance on their *Lender's Dependability* as a credit source than producers who exhibit less customer loyalty.

Table 3. Importance of Lender Attributes by Price Sensitivity and Loyalty

	Borrower Price Sensitivity		Borrower Loyalty	
Lender Attributes	**High**	**Not High**	**Strong**	**Not Strong**
Interest rate	4.54 [A]	4.37 [B]	4.43	4.56
Institution's stability	4.46	4.39	4.42	4.45
Lender's dependability	4.37	4.41	4.45 [A]	4.27 [B]
Ability to meet needs	4.35	4.32	4.34	4.31
Knowledge of agriculture	4.23	4.26	4.24	4.27
Timeliness in loan decisions	4.23	4.20	4.21	4.21
Lender relationship	4.19	4.14	4.20	4.13

Notes: Importance ratings are based on a five-point Likert scale (1 = not important, 5 = very important). Means denoted by superscript alphabetical letters A and B within each treatment variable are significantly different ($p > 0.05$).

Table 4. Econometric Results for Price Sensitivity and Loyalty Models

	Borrower Price Sensitivity			Borrower Loyalty		
Variable	**Coefficient**	***p*-Value**	**Mean**	**Coefficient**	***p*-Value**	**Mean**
Constant	−2.2334	0.0501		1.8223	0.0506	
Acres Farmed	0.000107	0.2709	1,494	−0.00017*	0.0693	1,471
Bank Use	0.244	0.4306	0.74	0.5321*	0.0888	0.74
Education	0.0915	0.1338	13.98	−0.0298	0.6318	13.93
FCS Use	0.5564*	0.0539	0.35	0.098	0.7416	0.34
Farmland Lease Ratio	0.0731	0.8501	0.52	−0.6596*	0.0920	0.52
Leverage	−0.6229	0.3021	0.26	−1.337*	0.0601	0.26
Off-Farm Income	0.00000591	0.1861	27,594	−0.00000448	0.3214	27,195
Age	0.0127	0.2128	52.09	—	—	—
Likelihood Ratio	13.9527	0.0830		16.6936	0.0195	

Note: An asterisk (*) denotes significance at the 10% level.

Table 4 gives the estimated logit coefficients, *p*-values, and associated means for the borrower price sensitivity and loyalty models. The two dependent variables reflect "high price sensitivity" versus "not high price sensitivity" and "strong loyalty" versus "not strong loyalty." Positive (negative) coefficient estimates of independent variables indicate that the variables increase (decrease) the likelihood of high price sensitivity in the borrower price sensitivity model and high loyalty in the borrower loyalty model.

The results from Table 4 suggest sourcing financing from the FCS significantly increases the likelihood of high price sensitivity at the 10% level. None of the remaining variables significantly influence farmers' interest rate sensitivity. In the borrower loyalty equation, Table 4 reveals that loyalty of borrowers declines with the rise of farmed acres, debt-to-asset ratios, and tenure (as measured by the farmland lease ratio). Use of bank financing also significantly increases the likelihood of strong producer loyalty.

The findings in Table 4 also reveal the absence of statistical significance, particularly in the price sensitivity results where *FCS Use* reflects the only significant difference between the two groups. Highly and not highly interest-rate sensitive borrowers are not statistically different in farm size, tenure, leverage, off-farm income, or age. The FCS's reputation of being price competitive likely explains its popularity with cost-driven borrowers.

Figure 1 portrays the marginal effects on the likelihood of strong borrower loyalty for different levels of treatment variables. Only statistically significant measures are reported: acreage, farmland lease ratio, and leverage. Each graph depicts the probability of strong loyalty as one independent variable changes while holding all other explanatory variables at their mean values. Response probabilities for each depiction sum to 100%.

The graphs in Figure 1 illustrate the decreasing likelihood of responding producers' loyalty to a single credit provider as levels of the independent variables increase. For instance, as *Acres Farmed* increases from the mean level of 1,471 to 3,000, the probability of strong borrower loyalty decreases from 69.5% to 63.7%. The maximum rates of change across the ranges of *Acres Farmed*, *Farmland Lease Ratio*, and *Leverage* are 24.3%, 13.9%, and 25.7%, respectively.

The regression analyses help identify producers who are likely to be sensitive to marginal interest rate changes and those who may demonstrate strong degrees of borrower loyalty. The econometric models reveal a significant, negative association for both *Leverage* and the *Farmland Lease Ratio* in the loyalty model. One plausible explanation suggests that the desire to reduce costs when profit margins are tight overwhelms the perceived benefits of lender relationships.

This study produces intriguing findings on the behavior of FCS and bank patrons. Regression results indicate that respondents who secure financing from the FCS are more likely to be highly price sensitive, while users of bank-supplied credit are more likely to be highly loyal producers. As noted earlier, the FCS tends to be price competitive, and therefore may attract borrowers who place a high value on price.

The farm business characteristics found to influence producers' decisions to be price-sensitive and/or loyal borrowers are similar to the factors compelling farmers to use FCS and/or bank financing. Dodson and Koenig (2003) explore a related issue by examining the customers of the FCS and commercial banks using the USDA's 2001 and 2002 Agricultural Resource Management Survey (ARMS). They conduct multivariate analysis using a binomial logit model to test the null hypothesis that the characteristics of FCS customers are statistically different from the attributes of bank patrons. The authors' findings reveal significant differences between borrowers receiving loans from the FCS and those receiving credit from commercial banks in 2001 and 2002. FCS borrowers manage larger farm operations, carry lower debt-to-asset levels, and exhibit less financial stress compared to bank customers.

Findings from our analysis show that FCS borrowers are more likely to be highly sensitive to debt costs, even though the farm size and leverage variables are not significant predictors of price sensitivity. Dodson and Koenig (2003) argue that these variables are significant characteristics of FCS customers. In the evaluation of borrower loyalty, customers of bank institutions are more likely to be strongly committed to a single lender. Furthermore, survey participants displaying strong loyalty are more likely to manage fewer acres and be less financially leveraged. The impact of the farm size variable in the regression equation is consistent with Dodson and Koenig's finding that commercial bank customers operate smaller farms. However, leverage has a significantly negative relationship. While beyond the initial scope of our study, clearly the relationships and differences between the FCS and commercial banks warrant further investigation.

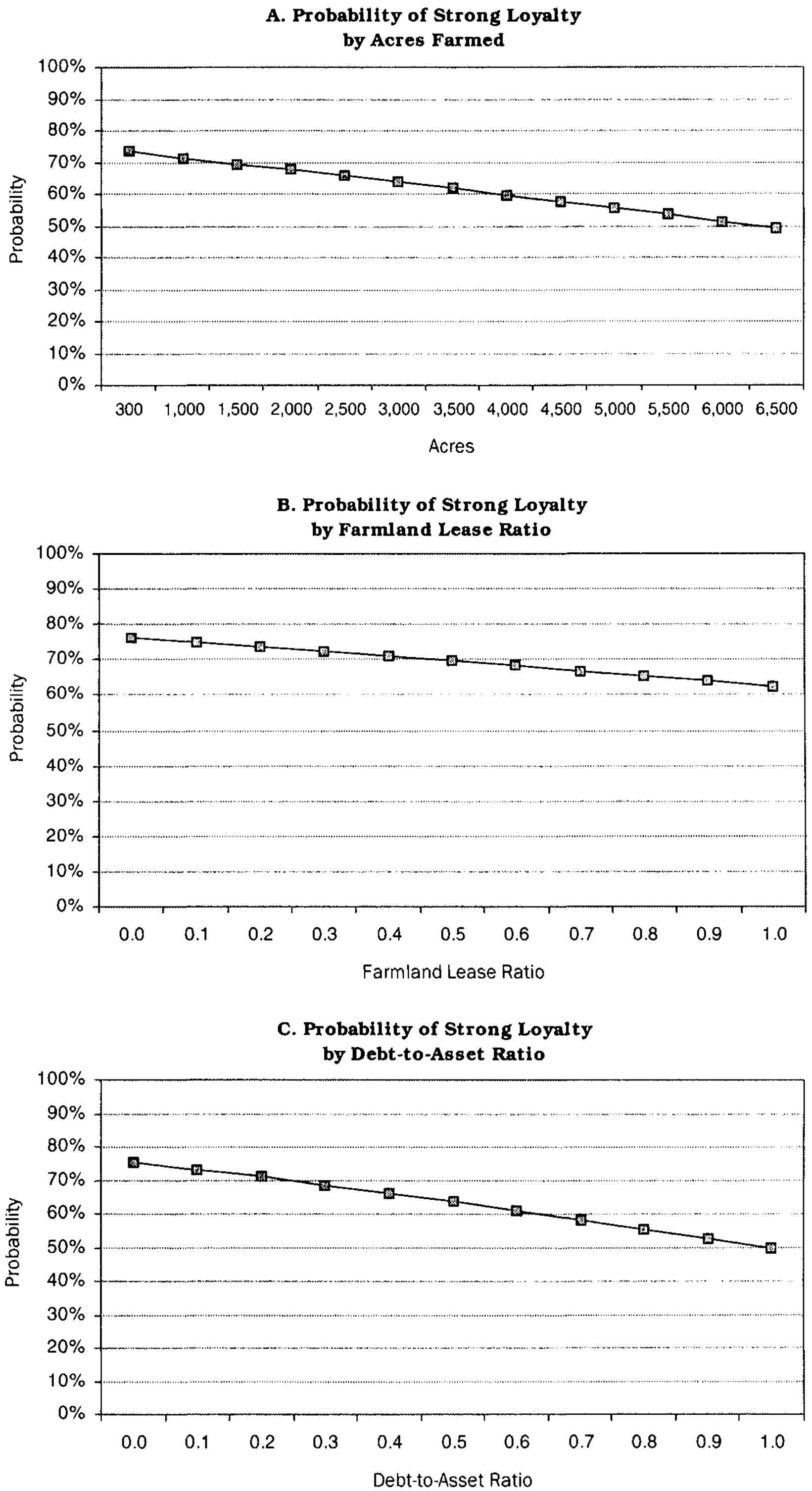

Figure 1. Effects of Acres Farmed, Farmland Lease Ratio, and Debt-to-Asset Ratio on the Probability of Strong Borrower Loyalty

Conclusions

The results from this study of Midwestern U.S. agricultural producers reveal the farm business characteristics of borrowers who are likely to be highly price-sensitive purchasers of credit and those who tend to demonstrate strong loyalty to a single credit provider. Our findings suggest FCS customers are more likely to be highly responsive to the lender's interest rates, whereas farmers who are less leveraged and tenured, operate fewer acres, and patronize bank institutions are more likely to have longer strong, loyal credit relationships. Our results provide empirical support for theories in the financial economics literature predicting that small firms benefit from establishing credit relationships and progressing these interactions to high levels of borrower loyalty.

From a lender's perspective, the knowledge of farm borrowers' profiles will help isolate the factors producers consider when making credit-source decisions. In an industry characterized by intense competition, as indicated by the recent growth of captive finance companies and the emergence of international financial institutions, the need for agricultural credit providers to differentiate themselves on various attributes is becoming necessary to enhance market strength.

Business success will depend on developing borrower-driven marketing strategies where market segmentation is based on perceived customer needs and preferences. The ability of agricultural lenders to attract new clients and retain existing customers depends on an understanding of the aspects of the lender-borrower relationship most important to credit users.

Future studies could further address the lender preferences of FCS and commercial bank borrowers. Supplemental research could evaluate the credit attributes valued by each group and identify significant similarities and differences in preferred lender characteristics. Based on findings from this survey, it would be interesting to examine why FCS patrons are more likely to be highly cost-driven and why users of bank financing are more likely to build strong loyalty.

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Combining Hedonic and Negative Exponential Techniques to Estimate the Market Value of Land

Leah J. Tsoodle, Allen M. Featherstone, and Bill B. Golden

Abstract

Given the importance of land valuation to various stakeholders, the objective of this research is to estimate a theoretically sound model to model the market value of land in Kansas, accounting for urban influence and site-specific characteristics. The model is estimated using data on all sales of agricultural land in Kansas between 1996 and 2004. Results indicate that the upward, urban pressure on price is greater for Kansas City relative to Wichita. Kansas City had a much slower rate of decay than either Wichita or cities with a population of more than 10,000.

Key words: hedonic model, negative exponential function, urban influence on land values

Changes in land values are a major concern to agricultural producers, landowners, community businesses, and financial agencies. Farm real estate accounts for more than 80% of the value of all farm assets in the United States, totaling approximately $1.13 trillion [U.S. Department of Agriculture/Economic Research Service (USDA/ERS), 2005]. Given the magnitude of this investment, agricultural land owners have a significant interest in changes in the value of their land. Large swings in land value have an impact on a landowner's net worth and borrowing ability. These changes spark the interest of financial agencies and may change their position on lending.

Movements in land prices affect sectors outside of agriculture as well. Changes in land prices encourage or discourage the conversion of agricultural land into residential or commercial development. Urban sprawl may drive up land prices near cities, discouraging production agriculture for two reasons. First, the increased land price makes it difficult for agricultural producers to purchase the land. Secondly, higher land prices may encourage producers to sell to developers who will convert the land out of agricultural production.

Given the importance of land to the various stakeholders, the objective of this research is to develop a theoretical model that estimates the market value of land in Kansas, accounting for urban influence. The market value of land is estimated using a hedonic model for the state of Kansas that includes factors related to urban sprawl. Using sales data from the

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Property Valuation Division of the Kansas Department of Revenue (2005), parameters for productive and locational attributes of the acreage sold are estimated. The sales data include all open-market, arms-length sales of agricultural land in Kansas between 1996 and 2004.

This research makes an important contribution to the current body of literature through the development of a hybrid hedonic model that takes into account urban influences. Doing so enables the estimates to incorporate both traditional characteristics of agricultural land and urban pressures specific to agricultural land.

Literature Review

Hedonic models are prominent in the land valuation literature. Rosen (1974) presented a general theoretical framework for using hedonic prices to analyze the demand and supply of attributes of differentiated products. Early applications of Rosen's theoretical model to agricultural land values include the works of Chicoine (1981), Miranowski and Hammes (1984), and Palmquist (1989).

Shi, Phipps, and Colyer (1997) combine agricultural and urban fringe models into a single equation model for farmland prices using cross-sectional and time-series data from multiple sources for counties in West Virginia. Urban influence is incorporated through a gravity model. The gravity model portion of the equation is an explanatory variable calculated by dividing county population by the squared distance of a county from three urban central business districts (CBDs). Shi, Phipps, and Colyer argue that including urban factors is essential because West Virginia is surrounded by major metropolitan areas and has many hobby farmers. They also include explanatory variables traditionally used in agricultural rent capitalization models, such as expected net returns, expected capital gains, and the real interest rate. The authors report that the distance ratio has the largest impact on per acre sale price at $132.60.

Shultz and Taff (2004) adopt a hedonic approach to estimate the implicit price of wetlands in areas of production agriculture. Using Geographic Information Systems (GIS) data, they separate eased and non-eased wetlands to determine whether the wetland was wet throughout the crop year (permanent) or might dry up (temporary). The permanent classification is found to be statistically and economically significant with each additional acre of non-eased and eased permanent wetlands, decreasing sale price by $161 and $321 per acre, respectively. Shultz and Taff state, "Our estimated implicit prices of eased and non-eased wetlands appear to be consistent with economic theory in that they reflect the relative opportunity costs associated with foregone agricultural production on different types of wetlands" (p. 510).

Capozza and Helsley (1989) report a positive relationship between the rate of urban growth and the price of housing. In two examples, they show that in rapidly growing cities, the value of expected future rent increases may account for at least half of the average price of land. Making some general assumptions about the values of the variables, the authors find that the ratio of the price of urban land net of the servicing costs to the value of agricultural land rent changes from 10.2 to 37.7 at respective growth rates of 2% and 4%. This finding suggests the alternative treatment of agricultural land leads to significant loss in property tax revenue to local governments.

In a 1990 follow-up study, Capozza and Helsley analyze a model of an expanding urban area in which household income and land rent follow stochastic processes. Both rents and prices decompose into simple additive components. Even with risk-neutral investors, uncertainty is found to affect both equilibrium land rents and prices in the urban area, partly because the conversion of land from agriculture to urban use is irreversible. However, growth has no effect on land rents, although it does impact the value of urban and agricultural land. Capozza and Helsley show that uncertainty delays the conversion of land from agricultural to urban use, reduces the expected city size, and adds an option value to agricultural land. It should be noted that the "option value" found by these researchers is shown to decline nonlinearly as the distance of the agricultural land from the CBD increases. Based on their results, land prices in two urban areas of comparable size will be higher in the riskier urban area. The authors conclude that uncertainty and growth help explain why agricultural land bordering an urban area sells for a large premium over land rents.

Quigg (1993) empirically tests real option-pricing models. Her results are based on a large sample of actual real estate transactions and indicate that real option-pricing models have explanatory value. She finds a mean premium of 6% of the land value for optimal development, indicating market prices do reflect a value to the option to wait to develop land.

Capozza and Sick (1994) integrate risk theories into spatial models of land markets. The model they develop provides several insights. According to Capozza and Sick, the model allows one to observe the effect of systematic rent risk on the option value of agricultural land. They observe that the price of land awaiting conversion increases with the growth rate of urban rents and unsystematic risk, but decreases with risk aversion. Yet, the effect of systematic risk is indeterminate because an increase in systematic risk increases overall risk and option value and decreases the value of the underlying urban land. Their findings show that when urban rents are riskier, then the option to develop is more valuable and the hurdle price is higher. Thus, development of land is prolonged and city size is smaller for a given CBD rent level. Finally, the authors note that prices for agricultural land decline with increasing distance from the urban area as a function of the expected time to development.

Anderson and Griffing's (2000) research focuses on estimating the lost tax revenues created by preferential treatment of agricultural land. They examine two contiguous urban counties in Nebraska using a negative exponential model of the difference between market value and use value per acre. Comparing market and use values for a land parcel, for the two counties they examine, the use-value assessments are 63.9% and 24.8% of market. Moreover, the rates of decay in the difference in value are very similar across these contiguous counties, implying this rate may be more generalizable beyond their data set.

Plantinga, Lubowski, and Stavins (2002) conducted "a national-level analysis of agricultural land value to understand how current land values are influenced by the potential for future land development." Their research provides empirical evidence of the impact of option values on farmland values. They incorporate uncertainty in the econometric model by using the variance of annual changes in population density as an explanatory variable. The population change variance is found to positively and significantly impact farmland values, suggesting option values associated with delaying irreversible land development are capitalized into the value of agricultural land. Another contribution of their research is that Plantinga, Lubowski, and Stavins decompose agricultural land values into the discounted value of agricultural production components and the discounted value of future land development. According to the authors, identifying these factors helps to determine the strength of the economic incentives for landowners to convert agricultural land. They conclude that future development rents represent a large portion of farmland values in locales surrounding urban areas.

Examining the effects of buyer type on conservation and preservation property purchases, Winfree, McCluskey, and Mittelhammer (2006) show that land has both value in its current use and value in potential future uses (option value). Their empirical results suggest land bought for conservation can have multiple future uses, such as housing or recreational purposes. The authors contend that the accuracy of land value estimates significantly influences the land purchased for conservation and preservation. Thus, buyers should consider all potential future uses when planning land purchases. Because conservation and preservation properties are public goods, the authors examine whether different types of buyers—public and private—value property differently. Their results reveal a statistical difference across buyer types in option values for undeveloped land. Private buyers are more likely to pay for land with residential development options, while public buyers tend to pay for properties with potential value in timber.

Our research combines hedonic and spatial elements from previous research, using each parcel's income-generating capability and location. The hedonic variables included are common to most hedonic studies (such as Schultz and Taff, 2004). Spatial information is incorporated adopting the negative exponential function used by Anderson and Griffing (2000). The major difference between this combined approach and prior gravity model research is that distances are parcel specific, rather than measured at the county level. Thus, the urban influence on each parcel can vary, instead of every parcel in a county being constrained to have the same distance.

Economic Theory

Capozza and Helsley (1989) develop a theoretical model that assumes capital is durable and landowners have perfect foresight. The price of urban land can be derived by summing four components: (*a*) the value of agricultural land rent, (*b*) the option value of development conversion, (*c*) the value of accessibility, and (*d*) the value of expected future rent increases. They view the capitalized value of agricultural rent and the value of capital improvements applied to the land as invariant to distance. The other two aspects of price, the option value of development conversion and the value of accessibility, are dependent on the location of the land in relation to the CBD.

Capozza and Helsley represent the price of developed land as:

$$(1)\quad P^d(t, z) = A/r + C + (1/r) * (T/\bar{L})\left[\bar{z}(t) - z\right] + (1/r)\int_t^{\infty} R_t(\tau, z)e^{-r(\tau-t)}\,d\tau,$$

where A is the value of agricultural rent and r is the discount or capitalization rate; C represents the value of capital improvements applied to the land. The value of accessibility depends on transportation cost T, mean lot size $\bar{L}$, and declines with distance z to the city boundary $\bar{z}(t)$.[1]

Capozza and Helsley state that urban growth affects the price of land and, in a static context, land price is proportional to land rent. This would make the price of land on the urban fringe equal to the value of agricultural land rent. In a dynamic model, they argue this is not the case. Specifically, the price of agricultural land is designated by:

$$(2)\quad P^a(t, z) = A/r + (1/r)\int_t^{\infty} R_t(\tau, z)e^{-r(\tau-t)}\,d\tau.$$

Substituting (2) into (1), the relationship between developed land and agricultural land can be denoted by:

$$(3)\quad P^d(t, z) = P^a + C + (1/r)(T/\bar{L})\left[\bar{z}(t) - z\right],$$

implying the price of developed land is equal to the price of agricultural land plus the capital improvements plus the option value of accessibility. Using Leibnitz' rule, Capozza and Helsley find that land is developed when its urban

[1] Models of urban land price theorize that the market value of the land per acre should decline as distance from the central business district increases.

use rent equals the opportunity costs of land and conversion capital. The rent outside the urban area is simply the agricultural rent. Rent at the edge of the urban area increases by the opportunity cost of the capital used to convert land for development. Rents rise inside the urban boundary by transportation costs per unit distance per unit land.

According to Anderson and Griffing (2000), little empirical research has evaluated the implications on tax expenditures of favorable treatment of agricultural land. In their analysis, they discuss more complex models developed by Capozza and show that market value exceeds the agricultural value, and this differential decreases with increasing distance from the CBD.

Anderson and Griffing's research focuses on estimating the lost tax revenues created by preferential treatment of agricultural land. They develop a negative exponential model of the spatial variation in the difference between the two sets of prices and integrate the area between them over the urban area. The negative exponential model implies that the distance to the CBD accounts for the difference between market value and use value. Empirically:

(4) $\ln(Diff) = \beta_0 - \beta_1 * Distance,$

where *Diff* is the difference between market value and use value, *Distance* is the distance of the parcel from the CBD, β_0 is the intercept of the function and represents the difference between market value and use value for a parcel located within the CBD, and β_1 is the rate per mile at which market value declines to use value. A concern when using the negative exponential function with time-series data is the function's reliance on distance as the sole influence on the difference between market value and use value; in essence, the influence that time may have on the land market is disregarded. We address this concern here by modeling time in addition to the negative exponential function in the model.

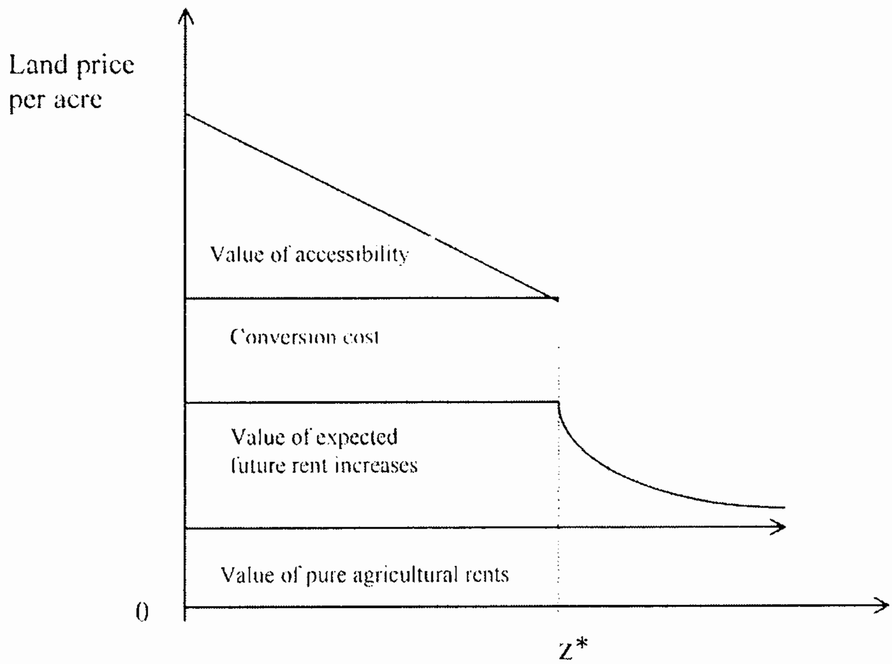
Methodology

The objective of this research is to estimate the market value of agricultural parcels in Kansas, taking into account the influence of urban location on the market price of agricultural land. A nonlinear model combining site-specific explanatory variables that are traditionally included in hedonic models with potential urban influences is estimated. Urban influence is incorporated using the negative exponential function adopted by Anderson and Griffing (2000). The negative exponential function is used to calculate the difference between market value and use value based on a parcel's distance from the central business district (CBD). Figure 1 illustrates graphically the premise of the negative exponential function with regard to land sales price.

The hybrid hedonic land price model assumes the price of land is determined by the summation of the product of the price and quantity of the characteristics of the parcel and the distance the acreage is from metropolitan statistical areas (MSAs) in Kansas. Although Kansas is a relatively agricultural state, it is composed of two larger metropolitan areas (Kansas City and Wichita). Urban forces may be stronger in states with more agricultural acres because there are virtually no expansion limitations such as geographic barriers. Consequently, it is especially important to include developmental pressures in estimating market value of agricultural land.

A double-log functional form was chosen for the model because it is a first-order Taylor series approximation of an arbitrary function commonly used in the literature and is easily interpreted. Using Box-Cox estimation, Nivens et al. (2002) found that the log form was appropriate for the dependent variable and more appropriate for the independent variables than the linear form.

The double-log empirical specification of the hedonic model used in this research is given by:



Source: Anderson (2002).
Note: Z* is the distance of a parcel from the central business district.

Figure 1. Analysis of Components of Per Acre Land Price

$$(5)\ LSPA = \beta_0 + \beta_1 * Lacres + \beta_2 * \%Irr + \beta_3 * \%ImpPast + \beta_4 * \%Grass + \beta_5 * Lprod + \beta_6 * Rolling + \beta_7 * PubUtil + \beta_8 * NoUtil + \beta_9 * PavedRoad + \beta_{10} * DirtRoad + \beta_{11} * NoRoad + \beta_{12} * D1996 + \beta_{13} * D1997 + \beta_{14} * D1998 + \beta_{15} * D1999 + \beta_{16} * D2000 + \beta_{17} * D2001 + \beta_{18} * D2002 + \beta_{19} * D2003 + \exp(\beta_{20} - \beta_{21} * KSCity) + \exp(\beta_{22} - \beta_{23} * Wichita) + \exp(\beta_{24} - \beta_{25} * minGreater10{,}000),$$

where *LSPA* is the estimate of the logged sale price, or market value, per acre, and *Lacres* is the logged total number of acres in the sales transaction. Prior research (Featherstone et al., 1993; Roka and Palmquist, 1997; and Xu, Mittelhammer, and Barkley, 1993) has shown that the expected sign on this coefficient is negative. The percent of irrigated acreage is designated as *%Irr*, *%ImpPast* is the percent of improved pasture, and *%Grass* is the percent of native pasture or rangeland. These estimates are relative to non-irrigated acreage, which is the default. Acreage with irrigation should generate more income and thus bring a higher price than dryland. However, both types of pasture should be worth less per acre than the non-irrigated default. Improved pasture should be worth less relative to dryland, but worth more relative to rangeland.

Lprod is the logged value of the weighted average productivity index.[2] The construction of *Lprod* arrays soil mapping units relative to their potential to produce crop growth using indices developed by the Natural Resources Conservation Service and Kansas State University (based on soil type and topographical characteristics).

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[2] County average rainfall was not included in the model because productivity and rainfall are highly correlated.

As shown by Tsoodle, Golden, and Featherstone (2006), per acre sale price increases as the productivity of the acreage increases.

Topographical codes describe whether the parcel is *Level* or *Rolling*. The *Rolling* binary variable is equal to one if more than 50% of the acreage in the sale is defined as rolling by the county appraiser, and zero otherwise. Because the coefficient is interpreted relative to level land, the expected sign is negative since rolling land is generally less productive than level land.

Utility codes provide information on the source (public or private) of utilities. *PubUtil* is a binary variable representing the presence of public utilities on the property, *NoUtil* indicates no utilities are present, and private utilities (*PrivUtil*) serves as the default. Private utilities are expected to be valued more than public or no utilities, so the anticipated signs on those variable coefficients are negative.

Access codes define the type of road access to the parcel (paved, semi-improved, dirt, or no road). *PavedRoad* is a binary variable for access from a paved road, *DirtRoad* indicates dirt road access, *NoRoad* indicates there is no road access, and the default is semi-improved (gravel) roads (*Semi-ImpRoad*). Paved roads should bring a premium relative to gravel roads. Dirt roads and no road access should discount the per acre sale price of land.

The *DYear* variables are binary variables representing the year of the sale and are included to capture the annual trend in land sales price. *DYear* is equal to one for the year in which the acreage sold; for example, if the sales year was 1996, then *D1996* was equal to one, and zero for all other years 1997 through 2004. The coefficients for the year binaries are interpreted relative to 2004 sales, so these coefficients are expected to be negative.

Components included in the exponential portion of the model explain urban influences on land price. The β_{20} parameter is the intercept term for the distance in miles to Kansas City (*KSCity*), and β_{21} is the rate of change in *LSPA* per additional mile of distance from *KSCity*. The β_{22} parameter is the intercept term for the distance in miles to Wichita (*Wichita*), and β_{23} is the rate of change in *LSPA* per additional mile of distance from *Wichita*. The β_{24} parameter is the intercept term for the minimum distance in miles between each parcel and any community with a population of more than 10,000 people (*minGreater10,000*). The β_{25} parameter estimate represents the rate of change in *LSPA* per additional mile of distance from communities with a population of over 10,000. The intercept terms represent the difference between the sale price and the use value when distance is zero, or the parcel is located in the CBD. The intercept represents the largest difference between use value and market value of the acreage sold. The distance variables are calculated using GIS data that measure the distance between a parcel and the two primary metropolitan areas in Kansas and the minimum distance between a parcel and a *minGreater10,000* community.

Interpretation of parameter estimates in this model, in most cases, is relatively straightforward. The parameter estimates for the logged independent variables can be interpreted directly as elasticities. Those variables in percentage form can also be interpreted as elasticities. For the case of binary variables, the elasticity of the binary variable equals the exponential of the variable's parameter estimate minus one (Halvorsen and Palmquist, 1980).

Data

The Property Valuation Division of the Kansas Department of Revenue (KDOR) is the main source of data. The sales data consist of actual arms-length, open-market agricultural land sales in Kansas between 1996 and 2004, and have over 23,000 complete observations. The data set contains the sales price and consists of all agricultural parcels in Kansas sold in the specified years. Information is included on parcel identification number, county number, sales class, certificate of value, month, year, sale type, sales price, sales validity code, agriculture use type, soil mapping unit, agriculture size, acres, building value, topographical codes, utility codes, and access codes. Definitions and descriptions of these codes are provided in the KSCAMA Residential/Agricultural Data Collection Course 1-104-2 (KDOR, 2005).

The distances between a parcel and the CBDs of Kansas City, Wichita, and communities with more than 10,000 people are calculated. Sales and GIS data are combined to estimate the distance variable, necessary to use the exponential function. The LEO System, designed by the Kansas Geological Society (2005), converts location reference (the legal description of a parcel) to a parcel's center point location in geographic (longitude, latitude) coordinates. The Geographic Information System (GIS) data for all Kansas cities came from the U.S. Geological Survey's Geographic Names Information System. Using Cartesian coordinate geometry, the geodesic distance is calculated between a parcel and all Kansas cities.[3]

To calculate distance, latitude and longitude are converted from decimal degrees to radian degrees using the following formulas:

(6) $Long\_Rad_i = Long_i\_Dec * (\pi/180)$,

(7) $Lat\_Rad_i = Lat_i\_Dec * (\pi/180)$.

The formulas used to calculate the distance are:

(8) $$AA = \sin(Lat\_Rad_i) * \sin(Lat\_Rad_{i+1}) + \cos(Lat\_Rad_i) * \cos(Lat\_Rad_{i+1}) * \cos(Long\_Rad_i - Long\_Rad_{i+1}),$$

(9) $CC = \arccos(AA)$,

(10) $Distance = Earthradius * CC$,

where AA is an intermediate calculation to use the "great circle" formula[4] for calculating geodetic distances using latitude and longitude in radians; Lat_Rad_i ($Long\_Rad_i$) and Lat_Rad_{i+1} ($Long\_Rad_{i+1}$) are the latitudinal (longitudinal) location in radians of each parcel and each city, respectively; CC is the arc cosine of AA; *Distance* is the geodetic distance in miles between each parcel and each city; and *Earthradius* is the earth's mean radius of 3,959 miles.[5] This would be the radius of a hypothetical perfect sphere having the same surface area as the earth.

Results

Summary statistics for the explanatory variables are reported in Table 1. The average sale price per acre of land in nominal dollars was $2,873/acre, with a range of $20 to $989,461 per acre.[6] Parcels that sold ranged from 0.03 to 1,994 acres, with a mean of 162. The average productivity index value was 1.03, indicating the average parcel sold consisted of soil that was slightly above the average quality of the entire state.

During the 1996–2004 period, 55% of the acres sold were non-irrigated cropland, in contrast to 4% irrigated, 7% improved pasture, and 34% rangeland. Most of the acreage sold (61%) was considered level terrain, with the remaining 39% characterized as rolling terrain. The percentages of sales with private, public, and no utilities were 9%, 10%, and 81%, respectively. The percentage of land sold with paved road access was 17%, and 53% of land sold had some kind of improved access other than pavement.

[3] When referring to distance on the earth, "geodetic distance" and "geodesic distance" are the same—i.e., the shortest path along the ellipsoid of the earth at sea level between one point and another.

[4] The online source for the "great circle" distance (GCD) is http://www.ac6v.com/greatcircle.htm.

[5] The mean radius is derived by averaging the center-to-surface distances on all points on the globe. For the formula used to calculate the radius, see Wikipedia, online at http://en.wikipedia.org/wiki/Earth_radius.

[6] The maximum value is based on conversations with developers who stated that four homes priced at about $500,000 could be built on one acre, leaving a net profit of about $300,000.

Table 1. Summary Statistics for Agricultural Parcels Sold in Kansas Between 1996 and 2004

	Statistic			
Variable Description and Name	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
Logged sale price per acre ($/acre)[a] (*LSPA*)	2,873	20,326	20	989,461
Logged total number of acres (*Lacres*)	162	183	0.03	1,994
Logged value of productivity index (*Lprod*)	1.03	0.22	0.01	1.68
Percent of non-irrigated acres (*%Non-Irr*)	0.55	0.42	0.00	1.00
Percent of irrigated acres (*%Irr*)	0.04	0.18	0.00	1.00
Percent of improved pasture acres (*%ImpPast*)	0.07	0.21	0.00	1.00
Percent of native pasture or rangeland acres (*%Grass*)	0.34	0.39	0.00	1.00
Property has level terrain (*Level*)	0.61	0.49	0.00	1.00
Property has rolling terrain (*Rolling*)	0.39	0.49	0.00	1.00
Property has private utilities (*PrivUtil*)	0.09	0.29	0.00	1.00
Property has public utilities (*PubUtil*)	0.10	0.30	0.00	1.00
Property has no utilities (*NoUtil*)	0.81	0.39	0.00	1.00
Access by paved roads (*PavedRoad*)	0.17	0.37	0.00	1.00
Access by semi-improved roads (*Semi-ImpRoad*)	0.53	0.50	0.00	1.00
Access by dirt roads (*DirtRoad*)	0.25	0.43	0.00	1.00
No road access (*NoRoad*)	0.05	0.23	0.00	1.00
Sale year binary variables:				
D1996	0.11	0.31	0.00	1.00
D1997	0.12	0.33	0.00	1.00
D1998	0.12	0.32	0.00	1.00
D1999	0.11	0.32	0.00	1.00
D2000	0.12	0.33	0.00	1.00
D2001	0.12	0.33	0.00	1.00
D2002	0.13	0.34	0.00	1.00
D2003	0.12	0.32	0.00	1.00
D2004	0.05	0.21	0.00	1.00
Distance of sale (miles) from:				
Kansas City (*KSCity*)	194.53	96.78	12.84	425.77
Wichita (*Wichita*)	120.51	62.96	3.02	295.89
Cities with population > 10,000 (*minGreater10,000*)	32.69	24.97	0.65	151.06
Number of Observations = 23,436				

[a] Dollar values are in nominal dollars.

About one-fourth of the sale acreage had dirt road access, and 5% of the land sold had no road access.

Sales occurred in all years with a similar number of observations (between 11% and 13%) in each year except 2004, when fewer sales (only 5%) occurred. The small number of 2004 observations is due to a conflict in the data collection and the timing of county reports; therefore, not all 2004 sales were included in the data. The distance to Kansas City ranged from 12.8 miles to 425.8 miles, with a mean of 194.5 miles. The average distance to Wichita was 120.5 miles, with distances ranging from 3.0 to 295.9 miles. Finally, the distance to cities with a population of over 10,000 ranged from 0.65 miles to 151.1 miles, with a mean of 32.7 miles.

A test for heteroskedasticity was performed and yielded a statistically significant result in the model. However, using out-of-sample testing, the unadjusted model had better predictive ability than models that corrected for heteroskedasticity. The out-of-sample testing was conducted by randomly partitioning the data into thirds and estimating the model on two-thirds, predicting for the remaining one-third, and testing the RMSE of the residuals. The procedure was carried out three times, and each time the out-of-sample OLS RMSE was lower than that of the model correcting for heteroskedasticity. Table 2 provides the parameter estimates and the explanatory power of the model assuming a homoskedastic error. Results yielded an R^2 of 57% and an RMSE of about 0.7180. Table 3 reports the percentage change calculated for the binary variables.

Most of the variables were significant at the 1% level, except percent improved pasture (*%ImpPast*), public utilities (*PubUtil*), no utilities (*NoUtil*), and dirt road access (*DirtRoad*) (Table 2). Improved pasture percentage was significant at the 5% level, and dirt road access was significant at the 10% level. Public utilities and no utilities were not statistically significant at any generally accepted level. With the exception of no road access, all variables had the expected signs.

Increasing total acres (*Lacres*) by 1% decreased sale price per acre by almost 46%. In comparison, Featherstone et al. (1993) and Nivens et al. (2002) found statistically significant acreage discounts of approximately 19% and 20%, respectively, in Kansas. Perry and Robison (2001) found only a 9% discount for increasing acreage in Oregon. The differences in these estimates may have to do with the inclusion of very small acreage sales. Because our research focuses on urban influences rather than purely agricultural sales, small acreages are included. However, inclusion of these sales may reflect developer purchasing tendencies as opposed to agricultural producer purchasing preferences.

Table 2. Combined Hedonic and Negative Exponential Model Results

Variable	Coefficient	Std. Dev.
Hedonic:		
Intercept	8.6692***	0.0362
Lacres	-0.4571***	0.0043
Lprod	0.0896***	0.0129
%Irr	0.8067***	0.0281
%ImpPast	-0.0578**	0.0253
%Grass	0.1878***	0.0130
Rolling	-0.0465***	0.0099
PubUtil	0.0097	0.0224
NoUtil	-0.0056	0.0165
PavedRoad	0.0911***	0.0134
DirtRoad	0.0227*	0.0119
NoRoad	0.1540***	0.0215
D1996	-0.4204***	0.0263
D1997	-0.3682***	0.0258
D1998	-0.2552***	0.0260
D1999	-0.2521***	0.0261
D2000	-0.2050***	0.0259
D2001	-0.1383***	0.0258
D2002	-0.1474***	0.0255
D2003	-0.0705***	0.0260
Negative Exponential:		
KSCity Intercept	0.3579***	0.0423
KSCity	0.0152***	0.0008
Wichita Intercept	1.0146***	0.0432
Wichita	0.0816***	0.0033
minGreater10,000 intercept	0.1614**	0.0800
minGreater10,000	0.2815***	0.0226
R^2 = 0.5658		
RMSE = 0.7180		

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Increasing land productivity (*Lprod*) increased per acre sale price by almost 9%. The productivity coefficient is somewhat lower than the 17% value reported by Nivens et al. (2002).

Large economic impacts came from changes in the composition of the sales acreage. Increasing the percent of improved pasture (*%ImpPast*) or rangeland (*%Grass*) lowered the respective sale price by approximately 6% and 19%. Relative to non-irrigated sales, increasing irrigated acreage (*%Irr*) raised the per acre price by almost 81%—a higher premium than that found by Featherstone et al. (1993). This difference may reflect the fact that our research does not include some of the variables that were used in other studies having more data associated with individual sale specifics. For example, the sales of irrigated land in our data do not incorporate information about whether the irrigation equipment was included in the sale price.

Elasticities for binary variables are reported in Table 3. Rolling land (*Rolling*) was discounted almost 5% per acre in sale price. This discount was anticipated because rolling land is less productive than level land. The coefficients of *PavedRoad* and *NoRoad* were significantly different from zero at the 1% confidence level, while the coefficients for public utilities (*PubUtil*), no utilities (*NoUtil*), and dirt road (*DirtRoad*) were not statistically significant. The presence of paved road access (*PavedRoad*) and no road access (*NoRoad*) increased the per acre sale price. While the premium for *NoRoad* (a little over 15%) may seem counterintuitive, a likely explanation is that this coefficient is picking up some geographic influences. Over 90% of the sales with no road access occurred in eastern Kansas where the average sale price is higher than in the rest of the state.

The coefficient on the year dummy variables was used to reflect changes over time in the entire land market. All years were significantly different from zero at the 1% level (Table 2). The negative signs indicate the nominal value of land has been increasing over time, since each year is relative to 2004. In addition, one would expect these coefficients to increase in absolute value as the time between the sale and 2004 increased. This trend holds except between 2001–2002 and 1998–1999 (Table 2). Between 2001 and 2002, the discount relative to 2004 was larger for 2002 than for sales in 2001. The discounts for 1998 and 1999 were almost virtually the same.

Table 3. Percentage Effects of Binary Variables for Combined Hedonic and Negative Exponential Model

Variable	Coefficient	% Change
Rolling	-0.0465	-0.0454
PubUtil	0.0097	-0.0097
NoUtil	-0.0056	0.0055
PavedRoad	0.0911	0.0954
DirtRoad	0.0227	0.0230
NoRoad	0.1540	0.1665
D1996	-0.4204	-0.3432
D1997	-0.3682	-0.3080
D1998	-0.2552	0.2252
D1999	-0.2521	-0.2228
D2000	-0.2050	-0.1854
D2001	-0.1383	-0.1292
D2002	-0.1474	-0.1371
D2003	-0.0705	-0.0681

With the exception of the *minGreater10,000* intercept, the coefficients estimated in the negative exponential portion of the model in equation (5) are statistically significant at the 1% confidence level (Table 2).[7] The coefficient on the *KSCity* intercept was 0.36, implying the difference between per acre market and use value of a parcel within the Kansas City central business district was 36%. The rate of decay, or rate at which market value moves to use value, was about 2% per mile. Similarly, the coefficient on the *Wichita* intercept was 1.01, implying per acre market value of a parcel within the Wichita central business district was 101% of use value. The decrease in value for Wichita was about 8% per mile. In essence, the difference between market value and use value for parcels in Wichita starts higher than for parcels located in Kansas City, but the difference declines much faster per mile as one moves away from Wichita. The difference between market and use value would dissipate for Wichita in one-fourth of the distance that it would take for the difference to disappear for parcels near

[7] Taken together, all intercepts with the corresponding decay rate can be interpreted as elasticities.

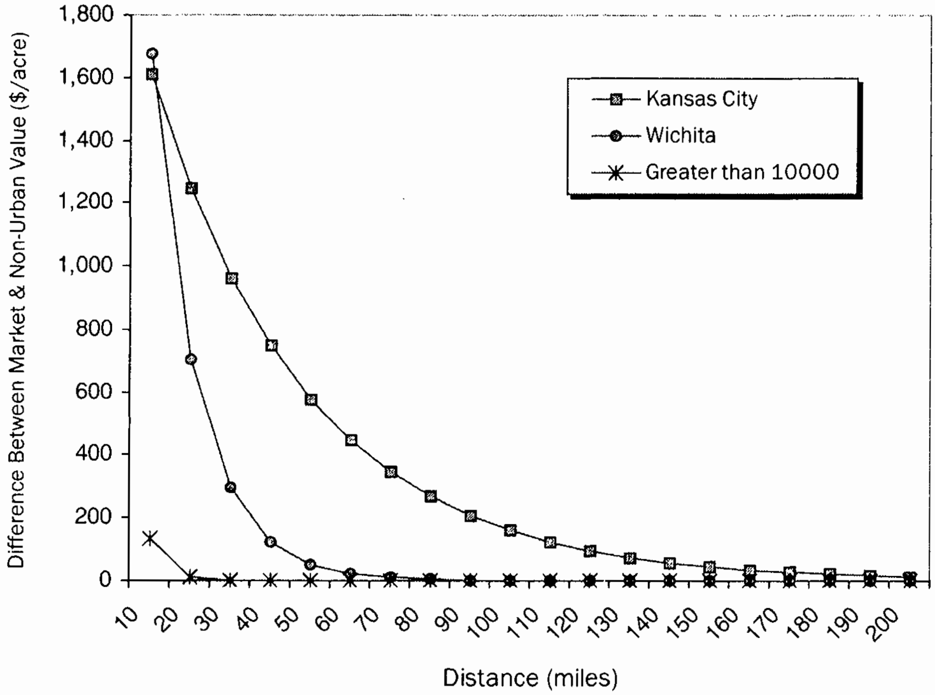

Figure 2. Difference Between Market and Non-Urban Value: Land Parcels in Kansas City, Wichita, and Cities with Greater than 10,000 Residents

Kansas City. These results differ from findings reported by Anderson and Griffing (2000), who note rates of decay of about 10% per mile for the two contiguous counties in Nebraska examined in their study.

As shown in Table 2, the coefficient on the *minGreater10,000* intercept was significant at the 5% level. It was much lower than either Kansas City or Wichita, implying that the difference between market and use value is much smaller for more rural areas. The decay rate for cities with more than 10,000 residents was much higher than for either Kansas City or Wichita. Using the minimum distance for this type of city resulted in a change of almost 28% per mile, or about 14 times faster than Kansas City and about three and one-half times faster than Wichita.

Figure 2 graphically displays the changes for Kansas City, Wichita, and the cities with greater than 10,000 residents. All series are calculated at the mean of all variables, except distance, which varies to illustrate the difference in the rates of decay. This graph illustrates the difference in decay rates for the three distance measures. The premium over use value for parcels within the Wichita central business district is slightly higher than for parcels located in the Kansas City central business district, likely due to the lower agricultural use value in the Wichita region. However, the difference between market and use value remains much larger for a much longer distance for parcels around Kansas City. For cities with populations greater than 10,000, market and use value converge by about 24 miles. For Kansas City and Wichita, market and non-urban use converge by 195 and 65 miles, respectively. This may be due to the differing growth patterns around Kansas City and Wichita, illustrating there is more upward pressure on sales price from the Kansas City area.

Summary and Conclusions

The model in this research included both a hedonic and a negative exponential specification. Both approaches are frequently used in the literature. The hedonic specification was used to capture that portion of land value attributable to agricultural productivity. The negative exponential specification (as used by Anderson and Griffing, 2000) was included to potentially capture the "option" value on land found by Capozza and Helsley (1990).

The data set used in our analysis was obtained from the Property Valuation Division of the Kansas Department of Revenue and consisted of all arms-length agricultural land sales (over 23,000) that occurred between January 1996 and December 2004. Each sale contained information on the site-specific characteristics of the acreage sold and the location of the parcel sold. The location information was used to calculate the distance of the acreage from Kansas City and Wichita and to calculate the minimum distance of the acreage from a city with a population greater than 10,000. These distances were incorporated using a negative exponential component in the model to capture the option value of potential development on sale price, or market value.

The objective of this research was to quantify the impacts of site-specific characteristics and urban pressures on agricultural land market value in Kansas. A semi-log hedonic model that combined site-specific characteristics with negative exponential distance functions was estimated. The distance measures included were calculated as the distance of the land sold to both Kansas City and Wichita, Kansas, and the distance between each parcel sold and all cities in Kansas with a population of over 10,000.

Parcels within the Wichita central business district received a slightly higher premium over use value, relative to those in the Kansas City area. However, the difference between market value (sale price) and use value remained much larger for a much longer distance to Kansas City, relative to distance to Wichita. Specifically, the upward, urban pressure on price is greater for Kansas City. The distance to cities with a population of over 10,000 was also statistically significant, but implied that the difference between use value and market value in rural areas is virtually zero. Reinforcing this notion is the high rate of decay for these areas, which was 14 times faster than that for Kansas City.

All of the coefficients on the negative exponential distance variables were statistically significant. However, the rate at which market value and use value converged was very different for all three areas. This result contrasts with the findings of Anderson and Griffing (2000), who document a similar decay for two contiguous urban counties in Nebraska.

In Kansas, agricultural land is taxed based on its use value rather than its market value. Our results suggest this state property tax policy differentially affects landowners involved in sales in different areas. Differential property tax rates impact land conversion, and this research could assist in formulating optimal property tax policy by aiding, for example, in establishing a "green belt" radius around urban areas. Our results imply that the distribution of tax burdens among owners and renters may be inequitable; in some areas, taxes may be passed on to renters. Therefore, landowners who own land outside Kansas City may be receiving a larger tax benefit than those who own land outside of Wichita, Kansas.

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Off-Farm Income and Farm Capital Accumulation: A Farm-Level Analysis

Carl J. Lagerkvist, Karin Larsén, and Kent D. Olson

Abstract

An intertemporal model in which farm capital accumulation and work choices by a single-agent farm household are interdependent is developed and tested using a farm-level data set. Estimation is done using a recursive two-step simultaneous censored equations model. The results of this study are of relevance for an understanding of structural change within the agricultural sector as they point toward the emergence of a dual farming structure and rigidity in off-farm work adjustments. Our findings suggest that off-farm income reliance is associated with a farm asset disinvestment strategy, that there is rigidity in off-farm income reliance, and that factors explaining farm capital growth indirectly affect the off-farm reliance.

Key words: agricultural sector, human capital, investment, off-farm work

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Review coordinated by Calum G. Turvey.

Off-farm work participation and investments in farm capital influence farmers' earnings and contribute to accumulation of human and physical capital. Boehlje (1992) defined the structure of the farm sector along five dimensions: (*a*) the size distributions of farms, (*b*) technology and production characteristics, (*c*) the characterization of the workforce, (*d*) resource ownership and financing pattern, and (*e*) inter- and intrasector linkages. Based on this structure, we observe that off-farm work and off-farm investments by farm households have increased steadily over several decades.

Census data for 2000 reveal a threefold increase in off-farm work by farm households since 1987, with net farm income constituting less than a third of farm household income in 1999 (Mishra et al., 2002). Moreover, the U.S. Department of Agriculture (USDA, 2005) reports two major changes in farm structure between 1989 and 2003. Farm size shifted toward the smallest and the largest sales classes, and production shifted whereby very large family farms and nonfamily farms produce a growing share of agricultural output. In addition, the USDA also reports that small-farm households typically receive substantial earned off-farm income, and this income is of vital importance for their livelihood.

The data on which our study is based (detailed below) confirm this ongoing development. Interestingly, our farm business records reveal that, although small farms (constant dollar sales <\$100,000) are the most dependent upon off-farm income, farms with sales between \$100,000 and \$250,000 have become increasingly dependent on off-farm income as well. The average off-farm income as a share of total household income has increased from 25% in 1993 to 56% in 2002 for this group of farms. At the same time, this farm class reveals a reduction in the share of farm assets and land from 40.9% in 1993 to 21.2% in 2002. Although farms with even higher sales in our data set also have increased their off-farm income, their share of farm assets and land has been maintained or even increased.

The ongoing concentration of agricultural production and off-farm income developments may have economic implications. A natural question to ask in developing an understanding of the ongoing structural change is whether there is interplay between off-farm and farm work and farm capital accumulation. Ahituv and Kimhi (2002) used an Israeli data set for 1971 and 1981 and formulated the household off-farm labor decision as a multinomial choice model. They report a strong negative association between the supply of off-farm labor and the farm capital stock, indicating the two variables can move in opposite directions because capital increases the marginal productivity of family labor (i.e., capital and farm work are technical complements), and vice versa.

We are not aware of any other work in which a joint analysis has been conducted of farmers' decisions to work off-farm, and their investments in farm capital. These decisions are vital for the life-cycle paths of farmers' human as well as physical capital. The emergence of a dual farming structure will be accentuated if some farm households, to a larger and persistent extent, rely on off-farm income and simultaneously disinvest in the farm business (as would be suggested if we find evidence of a negative relationship between off-farm income reliance and capital accumulation), while on the other hand some farm households, being less dependent on off-farm income, actually invest in their farm business. The underpinnings of these decisions are essential to our assessment, as they contribute to the overall development of the agricultural sector.

The objectives of this paper are to develop an intertemporal model in which farm capital accumulation and work choices by a single-agent farm household are interdependent and to jointly test farm household decisions to work off-farm, and their investments in farm capital. A farm-level data set is used, comprised of 252 sole proprietorships in southwestern Minnesota (Southwestern Minnesota Farm Business Management Association).

Time-series data are collected from the period 1993 through 2002, and estimation is done using a recursive two-step simultaneous censored equations model. An important advantage provided by this data set is that we are able to observe the differences in behavior of the farm households over a relatively long time period. For example, 165 of the 252 proprietorships are represented in the data set with four or more consecutive observations, thereby allowing us to address the issue of persistence of farm households in a true off-farm labor state dependence, in which past behavior has a casual connection with present behavior. Earlier investigations by Ahituv and Kimhi (2002) and Corsi and Findeis (2000) have found support for true state dependence, but both of these studies are limited to data from only two nonconsecutive time periods. Evidence of true state dependence would imply rigidity in off-farm labor adjustments.

Literature Review

Off-farm labor participation of farm households has been extensively analyzed (e.g., Lass, Findeis, and Hallberg, 1991), and recent work has addressed off-farm income and investments in farm and nonfarm assets (Andersson et al., 2005); wealth accumulation of farm households (Mishra and El-Osta, 2005); and the allocation of investment funds by farm households (Mishra and Morehart, 2001; Serra, Goodwin, and Featherstone, 2004; Davies et al., 2005). Analyses of off-farm labor supply typically include proxies for personal and/or household characteristics to estimate structural farm household models in a reduced-form methodology.

Several studies support a life-cycle pattern in off-farm work so that younger farmers are more likely to work off-farm (e.g., Ahituv and Kimhi, 2002; McNamara and Wiess, 2005; Ahearn, El-Osta, and Dewbre, 2006; Benjamin and Kimhi, 2006), and that farm experience is negatively related to off-farm work (e.g., Mishra and Goodwin, 1997; Mishra and Holthausen, 2002). In addition, existing studies have failed to find a significant relationship between household size and off-farm work participation (e.g., Mishra and Goodwin, 1997; Ahearn, El-Osta, and Dewbre, 2006). Mishra and Goodwin (1997), however, report that farm households with younger children are more likely to seek off-farm work.

Investments in nonfarm assets have grown in importance for U.S. farm households. Mishra and Morehart (2001) found that average total financial assets increased by 51% between 1992 and 1995. At the same time, average nonfinancial assets increased by 9.4%. Among the financial assets, investment in stocks, bonds, and IRAs more than doubled during the 1992–1995 time period. Mishra and Morehart also found that farms with off-farm income are more likely to invest off the farm. While a growing number of studies have analyzed determinants of off-farm investments, less attention has been directed to the extent to which off-farm investments influence decisions to work off-farm. Ahearn, El-Osta, and Dewbre (2006) found that off-farm interest and dividend income is positively related to off-farm work, suggesting a positive relationship between off-farm investments and off-farm work might be expected. As concluded by Serra, Goodwin, and Featherstone (2005), however, nonfarm investments, by providing nonwork income and wealth to the farm household, may reduce the incentives for off-farm work.

Various farm characteristics have been included in off-farm labor models. First, farm size has been found to be negatively related to off-farm labor decisions (Ahituv and Kimhi, 2002; Serra, Goodwin, and Featherstone, 2005; Benjamin and Kimhi, 2006). As noted by Goodwin and Bruer (2003), farm households operating larger farms might be less likely to seek off-farm income, as the on-farm effort required to operate a larger farm is influenced by the size of the operation.

Second, the tenure share has been found to influence labor decisions by farm households, as they might have different objectives and face different economic constraints in off-farm work participation given the ownership status of the farm operated. Work by Tavernier, Temel, and Li (1997) and Mishra and Holthausen (2002) found that off-farm work participation was negatively related to the degree of farm ownership. Serra, Goodwin, and Featherstone (2005), on the other hand, found support for a negative relation between the proportion of rented acres and off-farm work.

Third, it is standard in off-farm work participation models to include a dummy variable for whether or not the farm operation specializes in dairy. The assumption is that more labor-demanding types of farm operations will have a lower off-farm participation rate. Using an extended set of five specialization categories, Ahearn, El-Osta, and Dewbre (2006) indeed found that specialization in dairy was negatively related to the operator's off-farm participation, while specializations in cash crops, beef, and hogs and other livestock were positively related to off-farm labor participation.

Fourth, recent work by Ahearn, El-Osta, and Dewbre (2006) focusing on individual participation in the off-farm labor market (based on ARMS data),[1] and work by Shrestha and Findeis (2005) focusing on the off-farm employment rate (based on county-level data) have found evidence of a

[1] The Agricultural Resource Management Study (ARMS) is an annual farm survey, jointly conducted by the USDA's Economic Research Service and National Agricultural Statistics Service.

negative relationship between government payments and off-farm employment for the United States overall, and a mixed relationship when examining this relationship by type of payment on a regional basis. Moreover, Serra, Goodwin, and Featherstone (2005) concluded that the introduction of decoupled payments following the 1996 Federal Agriculture Improvement and Reform (FAIR) Act may have reduced the likelihood of off-farm work participation.

Finally, the leverage position was found by Furtan, Van Kooten, and Thompson (1985); Spitze and Mahoney (1991); and Mishra and Goodwin (1997) to influence off-farm labor supply. Specifically, income generated off-farm could alleviate a farm's financial constraints. Serra, Goodwin, and Featherstone (2005), however, found no support for the hypothesis that a lagged value of the farm's debt-to-asset ratio influenced the likelihood of off-farm work by the farm household.

Previous studies have recognized the importance of various local economic effects such as the structure of local labor markets (Hearn, McNamara, and Gunter, 1996; Ahearn, El-Osta, and Dewbre, 2006); county differences in volatility in off-farm wages (Goodwin and Bruer, 2003); and average county salaries (Serra, Goodwin, and Featherstone, 2005). Results from Mishra and Goodwin (1997) support the notion that distance to town is negatively related to off-farm labor supply. The recent study by Ahearn, El-Osta, and Dewbre (2006), however, found that local area variables such as unemployment rate, employment in specific industries, and urbanization were rather unimportant in explaining off-farm labor participation likelihood.

Conceptual Model

Farm household models suggest that farm production and off-farm labor decisions are likely to be simultaneous (Nakajima, 1986; Phimister and Roberts, 2006). Following Huffman's (1980) seminal work, and especially work by Skoufias (1996) and Ahituv and Kimhi (2002), this section develops an intertemporal lifetime income model in which farm capital accumulation and work choices by a single-agent farm household are interdependent (intra-household time allocation is ignored for simplicity).

Assuming the amount of leisure is fixed, the farmer chooses the amount of off-farm work L and farm work F so as to maximize the value of the state variables: farm capital K, off-farm-specific human capital h^{of}, and farm-specific human capital h^{f}. Installing and uninstalling farm capital are assumed to consume resources, which are incorporated into the model as losses in output.

Following, for example, Hubbard, Kashyap, and Whited (1995), an adjustment cost function $g(K, I)$ (where I denotes gross farm investments) that is linearly homogeneous in its arguments is assumed. In addition, switching between off-farm and farm work, as well as time adjustments of off-farm work in itself by the farm operator, may not be frictionless. Search costs and other types of transaction costs, as well as interplay between off-farm-specific and farm-specific human capital in affecting such frictions, can influence the income earned.

We introduce an adjustment cost function (which might include internal and external as well as direct and indirect costs) for off-farm work, $c^{of}(h^{of}, h^{f}, L)$, to capture such effects. Moreover, a time dependence in off-farm work is therefore suggested whereby a farm household that received off-farm income in the past is more likely to persist in that state.

The flow of household income is then given by:

$$(1)\quad D = Awh^{of}L + p\left[f\left(A, h^{f}, K, F, \theta\right) - g(K, I)\right] - p^{I}I - c^{of}\left(h^{of}, h^{f}, L\right),$$

where A is intrinsic ability, w is the off-farm (per unit of human capital) wage rate,

p is price of farm output, f is the farm output function, θ is a stochastic productivity shock, and p^I represents the price of the physical capital asset input. Let E_t denote the expectations operator conditional on the information at time t, and let $\beta = 1/(1 + r)$ represent the one-period discount factor, in which r is the required return on equity. Thus, the optimization problem for the farmer is specified as:

$$\text{(2)} \quad \max_{I,L,F} \left\{ E_t \left[\sum_{s=t}^{\infty} \left(\prod_{u=t}^{s} \beta_u \right) D_s \right] \right\},$$

subject to the dynamics of the stock variables and a time constraint:

$$\text{(3)} \quad K_{t+1} = I_t + (1 - \delta) K_t,$$

$$\text{(4)} \quad h_{t+1}^{of} = L_t + h_t^{of},$$

$$\text{(5)} \quad h_{t+1}^{f} = F_t + h_t^{f},$$

$$\text{(6)} \quad \bar{T} = L_t + F_t,$$

where δ is the rate of capacity depreciation of previously acquired investment goods, and $\bar{T}$ denotes fixed time devoted to any combination of off-farm and farm work. Following Ahituv and Kimhi (2002), equations (4) and (5) assume that type-specific human capital changes over time due to accumulated experience without depreciation. Let λ, μ^{of}, μ^{f}, and Γ denote the co-state variables attributed to each asset category of the stocks of physical and human capital, and the shadow value of the fixed time constraint, respectively. The Euler equations governing the optimal allocation of physical and human capital that solve (2) in an interior solution are:

$$\text{(7)} \quad \frac{1}{1 + r_t} \left\{ p_t \left[\frac{\partial f}{\partial K_t} - \frac{\partial g}{\partial K_t} \right] + (1 - \delta) \left[p_t^I + p_t \frac{\partial g}{\partial I_t} \right] \right\} = p_{t-1}^I + p_{t-1} \frac{\partial g}{\partial I_{t-1}}$$

and

$$\text{(8)} \quad \left(A\omega_t h_t^{of} - \frac{\partial c^{of}}{\partial L_t} \right) - \left\{ \left(A\omega_t L_t - \frac{\partial c^{of}}{\partial h_t^{of}} \right) - (1 + r_t) \left(A\omega_{t-1} L_{t-1} - \frac{\partial c^{of}}{\partial h_{t-1}^{of}} \right) \right\} = p_t \frac{\partial f}{\partial F_t} - (1 + r_t) p_{t-1} \frac{\partial f}{\partial F_{t-1}} - \left(p_t \frac{\partial f}{\partial h_t^f} - \frac{\partial c^{of}}{\partial h_t^{of}} \right).$$

Equation (7) characterizes the optimal path of physical investments for which the farm operator is indifferent between investing today ($t - 1$) or waiting until tomorrow (t). The marginal cost of investing today should equal the expected marginal return on capital invested and savings that are to be recovered tomorrow from having to invest $(1 - \delta)$ units less in period t in order to obtain the same level of physical capital in the subsequent period and onward.

Equation (8) combines the Euler equations for off-farm-specific human capital and farm-specific human capital, respectively, as they each separately equal the intertemporal shadow value of the time constraint. It should be noted that equation (8) is structurally equivalent to Ahituv and Kimhi's (2002) equation (6) if the co-state variable μ^{of} is held constant [i.e., $d/dt(\mu^{of}) = 0$].

Expression (8) characterizes the farm household indifference between the two available sources of income. The left-hand side of the expression represents the marginal condition for off-farm work, and the right-hand side is the corresponding expression associated with working on the farm. The first term on the left-hand side is the marginal cash flow from changing the off-farm work time, while the second term represents the marginal cash flow from a change in off-farm-specific human capital.

Similarly, the first two terms on the right-hand side of equation (8) represent the intertemporal change in marginal revenue of farm work, while the term in large parentheses is the marginal revenue from altering the stock of farm-specific human capital.

Empirical Models and Estimation Strategy

The empirical model developed in this section follows a reduced-form methodology that uses general predictions from the economic models outlined above to guide the empirical work. Our model specification follows the general specification in Maddala (1983) for a simultaneous-equations model stated in continuous dependent variables before censoring.

Our model includes one off-farm labor supply model which is estimated jointly with a farm capital accumulation model. Our goal is to estimate the likelihood of farm household reliance on off-farm income and to address the issue of interrelation between off-farm income reliance and farm physical capital accumulation. In addition, because not every farm household receives off-farm income, a censoring issue underlies the empirical model. A central issue here is whether farm capital is endogenous to off-farm income reliance.

As a preliminary test of our approach, we estimated the system:

$$y_1^* = \boldsymbol{\beta}_1\mathbf{x}_1 + \gamma y_2 + \varepsilon_1 \quad \text{(off-farm income)},$$
$$y_2 = \boldsymbol{\beta}_2\mathbf{x}_2 + \varepsilon_2 \quad \text{(farm capital)},$$

where y_1 = the annual share of off-farm wages, salaries, and business income (OFWSBI) in relation to the total of OFWSBI and net cash farm income to the farm household, with y_1 censored at 0; y_2 = log of real farm capital stock; $\mathbf{x}_1$ and $\mathbf{x}_2$ are vectors of explanatory exogenous factors in each equation, respectively; and ε_1 and ε_2 are the stochastic disturbance terms. The exogeneity of y_2 is tested by a t-test with the hypothesis that $\Psi = \sigma_{12}/\sigma_2^2$ equals zero (i.e., that the correlation between ε_1 and ε_2 equals zero) (Greene, 2002). Our findings clearly reject exogeneity (p-value = 0.0153).

To allow for endogeneity of off-farm income in the formation of farm capital as well as endogeneity of farm capital in the off-farm income model, we apply a two-step maximum-likelihood procedure following Blundell and Smith (1986) and Greene (2002, section E21.6.2). Formally, the model structure is written as:

$$\text{(9)} \quad y_{i1}^* = \gamma_1 y_{i2} + \boldsymbol{\beta}_1\mathbf{x}_{i1} + \varepsilon_1 \quad \text{(off-farm income)},$$
$$y_{i2} = \gamma_2 y_{i1} + \boldsymbol{\beta}_2\mathbf{x}_{i2} + \varepsilon_2 \quad \text{(farm capital)},$$

where $[\varepsilon_1, \varepsilon_2]$ is $BVN[(0, 0), (\sigma_{11}, \sigma_{12}), \sigma_{12}]$. The dependent variable in the off-farm income model is again censored at the lower limit $(L_i) = 0$, but the dependent variable in the farm capital equation is observed without censoring.

The two-step procedure is conducted in two joint parts. In the first part, the focus is on estimating $(\gamma_1, \boldsymbol{\beta}_1)$. In the first step here, $\pi_2 = \mathbf{x}_{i2}\boldsymbol{\beta}_2$ is estimated by ordinary least squares (OLS) regression on y_2. The second step then estimates γ_1, $\boldsymbol{\beta}_1$, σ_{11} by maximum likelihood in the censored regression model in the off-farm income equation while correcting for the asymptotic covariance matrix (Murphy and Topel, 1985). Analogously, in the second part, to estimate $(\gamma_2, \boldsymbol{\beta}_2)$, we first estimate $\pi_1 = \mathbf{x}_{i1}\boldsymbol{\beta}_1$ by maximum likelihood using the censored off-farm income equation, and then apply predicted values together with $\mathbf{x}_{i2}$ in an OLS regression of y_2 while correcting for the asymptotic covariance matrix (Murphy and Topel, 1985).

Variable Justification

The dependent variable in the off-farm income model (henceforth denoted "off-farm income share") is the annual share of off-farm wages, salaries, and business income (OFWSBI) in relation to the total of OFWSBI and net cash farm income of the farm household. This measure is believed to represent the degree of reliance of off-farm income

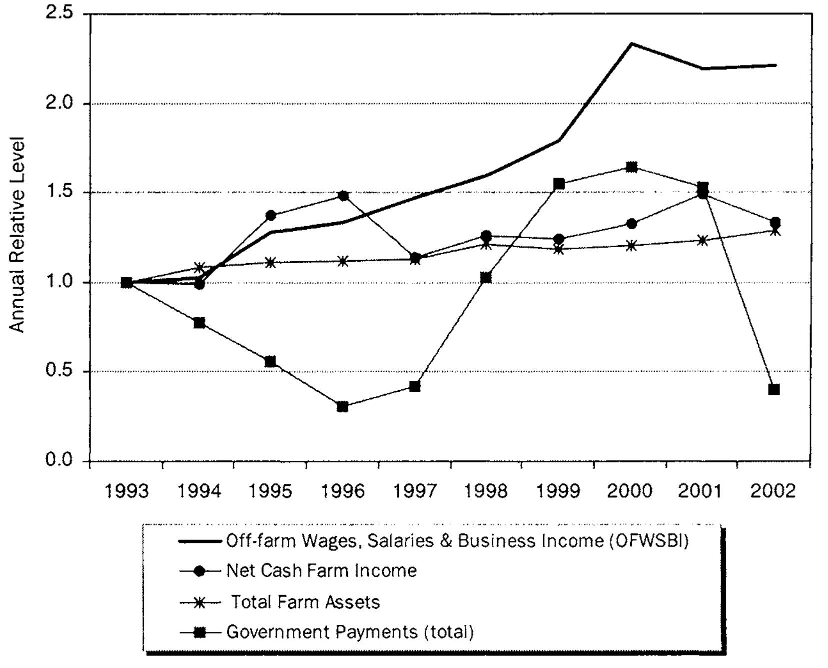

Figure 1. Relative Changes in Sources of Farm Household Income and Farm Assets: Southwestern Minnesota Farm Business Management Association Records, 1993–2002

sources in a more direct manner than hours worked off-farm and work status, which are the typical dependent variables used in the off-farm work-choice literature (e.g., Mishra and Goodwin, 1997). Moreover, because it is a continuous variable, this share makes our dependent variable different from binary or multinomial choice models typical in off-farm labor estimations.

This choice of dependent variable, however, implies the data must be considered as cross-sectional since, to our knowledge, dynamic Tobit models allowing for endogeneity of explanatory variables do not exist in the present literature. Consequently, based on the chosen procedure, we will not be able to disentangle the state dependence of off-farm income into a true state component and a component related to persistence due to individual heterogeneity.

Relative to their own levels in 1993, the level of off-farm wages, salaries, and business income has more than doubled while the levels of net cash farm income and total assets have increased less than half (Figure 1). Government payments exhibit a pattern almost identical to the U.S. average for the 1993–2002 period (USDA, 2005). Payments peaked in 1993 due to high feed grain production, and in 2000 due to large ad hoc and emergency payments. In absolute levels, the average share of OFWSBI in relation to the total of OFWSBI and net cash farm income increased from 14.8% in 1993 to 22.5% in 2002. These southwestern Minnesota averages are similar to the national averages (based on the USDA's ARMS survey data) of 40.4% of total farm household income coming from off-farm sources for large farms and 17.7% for very large farms. Further, the share of farm households in our sample that do not report any OFWSBI has decreased from 28.4% in 1993 to 16.1% in 2002 (i.e., more farm households receive off-farm income).

The dependent variable in the capital accumulation model is the log of the real

Table 1. Definitions and Descriptive Statistics of Variables in Models Estimated

Variable	Definition	Mean	Std. Dev.
OFI SHARE	Off-farm income share, i.e., share of off-farm wages, salaries, and business income (OFWSBI) in relation to the total of OFWSBI and net cash farm income	0.219	1.446
log(*TOT ASSETS*)	Log of real total farm assets[a]	5.85	0.294
OP AGE	Age of senior operator (years)	47.10	10.58
FARMING YRS	Senior operator's years in farming	24.08	10.53
LIV_EXP	Real family living expenses[b] ($)	31,709	14,627
HH_SIZE	Number of family members in household	3.52	1.60
NF_INVEST	Real nonfarm investments[b] ($); includes savings, stocks and bonds, retirement accounts, real estate, life insurance, and debt	97,861	121,713
TOT ACRES	Farm size, by total acres operated	635.2	345.7
TENURE_SHARE	The share of rented land to the sum of owned and rented land	0.626	0.307
CROP	Dummy variable for specialized crop production (=1 if more than 70% of farm gross sales is from crop production; 0 otherwise)	0.33	0.47
DAIRY	Dummy variable for specialized dairy production (=1 if more than 70% of farm gross sales is from dairy production; 0 otherwise)	0.017	0.13
HOG	Dummy variable for specialized hog production (=1 if more than 70% of farm gross sales is from hog production; 0 otherwise)	0.0396	0.195
BEEF	Dummy variable for specialized beef production (=1 if more than 70% of farm gross sales is from beef production; 0 otherwise)	0.042	0.20
PROF MARG	Operating profit margin (return to farm assets ÷ value of farm production); the value of farm production is gross farm income minus feeder livestock purchased and adjusted for inventory changes in crops, market livestock, and breeding livestock	0.195	0.219
ASSET TURNOVER	Asset turnover rate (value of farm production ÷ average farm assets)	0.32	0.20
DEBT-ASSET	Debt-to-asset ratio (total farm liabilities ÷ total farm assets)	0.393	0.236
GOV PAY	Real government payments (all types)[b] ($)	24,942	22,973
FIN_DISTRESS	Predictor of financial distress, z – 1: equals total farm assets ÷ the sum of 3.3 times net farm income before extraordinary items + operating expenses + 1.4 times retained earnings + 1.2 times net working capital (i.e., total farm current assets minus total farm current liabilities)	0.54	0.282
COUNTY_POP	County population density: county population ÷ county area (acres)[c] (serves as a proxy for local labor market characteristics)	0.033	0.0094

[a] Gross Domestic Product Implicit Price Deflator used for deflation (www.economagic.com).
[b] Consumer Price Index U.S. City Average used for deflation (www.economagic.com).
[c] Source: Minnesota Department of Administration, 2007 (www.demography.state.mn.us/estimates.html).

value of total farm assets. Figure 1 also portrays the annual relative changes in total farm assets between 1993 and 2002. Overall, the value of real farm capital has increased 29% over the 1993–2002 period.

Definitions and summary statistics for each variable used in the empirical model are reported in Table 1. The independent variables used in the off-farm work model include operator and farm household characteristics such as operator's age, experience, farm household measures, nonfarm investments, farm characteristics, government payments, state dependence in off-farm income reliance, and a local labor market component.

Analyses of off-farm labor supply typically include proxies for personal and/or household characteristics. We follow this convention by incorporating variables

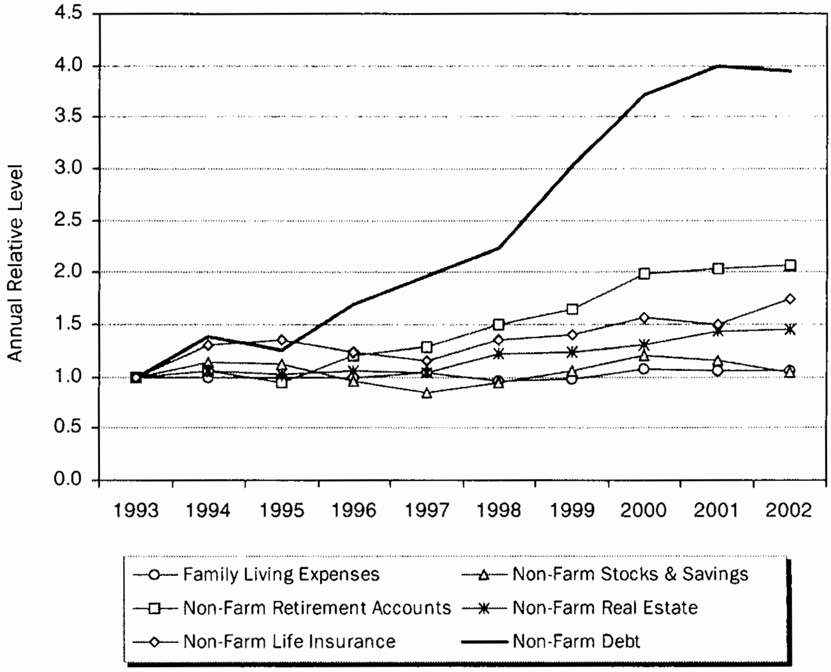

Figure 2. Annual Relative Changes in Non-Farm Investment and Family Living Expenses: Southwestern Minnesota Farm Business Management Association Records, 1993–2002

related to the farm household. First, the number of total family members is included. A larger farm household might be more likely to rely on off-farm income because the family can operate the farm while having one or more family members working off-farm. Moreover, a larger family reasonably implies presence of children. Second, we include family living expenses as an explanatory variable. We hypothesize that higher living expenses, either as a result of a larger farm household or by seeking a higher standard of living, is positively related to off-farm reliance.

To our knowledge, the relationships between off-farm labor and off-farm investment have not been examined in the literature. In this study, nonfarm investment is represented by an aggregate of savings, stocks and bonds, retirement accounts, real estate, life insurance, and debt because the composition of the wealth portfolio of farm households with and without off-farm income is likely to be different (Mishra and Morehart, 2001). Thus, it is hypothesized that farm households which, for one reason or another, invest in an off-farm wealth portfolio, might seek off-farm income as a complement to farm income to alleviate farm income risks. Figure 2 displays the development of nonfarm investment for the study sample used.

Five farm characteristics are included in the off-farm labor model. First, farm size (*TOT_ACRES*) is included as it has been found to be negatively related to off-farm labor decisions. Second, we include the tenure share (*TENURE_SHARE*) since tenure regimes have been found to exert an influence on off-farm work. Third, four specialization dummies are incorporated (*CROP*, *DAIRY*, *HOG*, and *BEEF*), defined in accordance with the Southwestern Minnesota Farm Business Management Association records from which data are provided on the basis of the farm having 70% or more of sales from a given category. ARMS data (USDA, 2005) reveal that commodity specialization affects off-farm earning opportunities. Of interest here is that specialized hog and dairy farming requires a large time commitment, leaving limited opportunities for off-farm work. Fourth, government payments (*GOV_PAY*) are included as our data allow us to add insights to the regional effects of such support.

Fifth, we maintain the hypothesis that farm households with farm financial difficulties might be more likely to seek off-farm work in order to sustain themselves. In keeping with Graham (1996) and MacKie-Mason (1990), we use a variant of Altman's (1968) original ZPROB specification as a predictor of financial distress (*FIN_DISTRESS*) in the farm operation; the leverage position by itself is not a direct measure as to what extent the farm family might seek off-farm income to alleviate financial problems. For two observations, our predictive measure resulted in a negative value. Farmers with negative values of this measure are most likely to experience financial difficulties. Since the predictive measure is constructed whereby higher values imply lower profitability, negative values would introduce a bias in the results. Consequently, these observations were excluded from the final sample.

To address the issue of state dependence in off-farm income reliance, we include the lagged share (*OFI_SHARE*) of OFWSBI in relation to total household income as an explanatory variable. Work by Corsi and Findeis (2000) and Ahituv and Kimhi (2002) suggests that the previous off-farm labor state is relevant in off-farm labor participation choices.

Finally, county population density (*COUNTY_POP*) is included as a proxy for local labor market characteristics. We hypothesize that this density is positively related to off-farm work accessibility and negatively related to various transaction costs associated with seeking off-farm work.

The independent variables used in the capital model include operator characteristics such as operator's age and experience, farm size, tenure share, and government payments. Farm specialization is represented by four dummy variables for farms specializing in crop, dairy, hog, and beef production. Farm operation efficacy is represented by the operating profit margin (*PROF_MARG*) and the asset turnover rate (*ASSET_TURNOVER*). The financial status of the farm operation is represented by the debt-to-asset ratio (*DEBT-ASSET*) and the predictive measure of financial distress (*FIN_DISTRESS*).

Results

The data used in this study were obtained from the Southwestern Minnesota Farm Business Management Association. The sample includes data from 252 sole proprietorships, with time series collected from the period 1993 through 2002. Our working sample includes 1,452 observations. An important advantage provided by this data set is that it allows us to observe the differences in the behavior of the farm household over a relatively long time period. One hundred sixty-five proprietorships are represented in the data set with four or more consecutive observations. The off-farm income reliance results are presented first, followed by the farm capital stock results.

Off-Farm Income Equation

Parameter estimates for the off-farm income share model are reported in Table 2. The sign of the lagged share of off-farm income (*OFI_SHARE*) is positive and highly significant. This finding suggests that a farm household which, to a greater extent, has relied on earned off-farm income in the past is more likely to persist in such income dependence in the future.

Consistent with our theoretical model, reasons for such state dependence might include higher off-farm wages for those with more off-farm work experience, which affects the opportunity cost of farm work

Table 2. Maximum-Likelihood Estimates (Tobit) of Off-Farm Income Share by Farm Households in Southwestern Minnesota, 1993–2002

Variable	Coefficient	*p*-Value
Intercept	0.412	0.257
Lag-1 Off-Farm Income Share (*OFI_SHARE*)	0.08	< 0.0001
Log of Total Farm Assets (log(*TOT_ASSETS*))	0.211	0.0001
Operator Age (*OP_AGE*)	0.034	0.0224
Operator Age Squared (OP_AGE^2)	−0.0003	0.0829
Years in Farming (*FARMING_YRS*)	−0.015	0.0016
Family Living Expenses (*LIV_EXP*)	0.3×10^{-5}	0.0792
No. of Household Members (*HH_SIZE*)	0.006	0.6572
Non-Farm Investments (*NF_INVEST*)	0.28×10^{-6}	0.0831
Total Acres Operated (*TOT_ACRES*)	−0.00039	< 0.0001
Tenure Share (*TENURE_SHARE*)	0.212	0.0001
Crop Dummy (*CROP*)	0.1787	< 0.0001
Dairy Dummy (*DAIRY*)	−0.23	0.1044
Hog Dummy (*HOG*)	−0.077	0.4063
Beef Dummy (*BEEF*)	−0.065	0.5027
Government Payments (*GOV_PAY*)	0.177×10^{-5}	0.0731
Predictor of Financial Distress, $z - 1$ (*FIN_DISTRESS*)	0.542	< 0.0001
County Population Density (*COUNTY_POP*)	−2.25	0.2458
σ	0.602	< 0.0001

Log Likelihood = −1,164.414
No. of Observations = 1,338

both directly through the relative changes in stocks of human capital as well as indirectly through the adjustment cost function for off-farm work.

Local labor market characteristics, as captured by the county population density (*COUNTY_POP*), have no significant effect on the off-farm income share. Farm size (by operated acres, *TOT_ACRES*), as well as farm capital [log(*TOT_ASSETS*)], has a negative impact on the off-farm income share, and the impact of farm capital is stronger than that of farm size (by acres). The latter finding is central to the question of endogeneity of capital stock to off-farm labor decisions. Our finding is consistent with the Israeli results reported by Ahituv and Kimhi (2002) for off-farm work participation, as well as with the results of Goodwin and Bruer (2003), who found that larger firms (by capital) imply less off-farm employment.

The coefficients of age of senior farm operator (*OP_AGE*) and age squared (OP_AGE^2) corroborate the familiar nonlinear effect of age reported in off-farm work participation studies. The latter finding is also supported by the negative relation found between off-farm income share (*OFI_SHARE*) and the number of years spent as a farmer (*FARMING_YRS*). As advised by Serra, Goodwin, and Featherstone (2005), this life-cycle pattern needs a cautious interpretation because our data are based not on individual but rather on total household decisions.

The results for the two farm household characteristics included in the model are mixed. Family living expenses (*LIV_EXP*) is, as expected, positively and weakly significantly related to the off-farm income share, but the household size (*HH_SIZE*), although estimated with a positive sign, is not significant. The latter finding suggests off-farm income reliance is more related to standard of living (i.e., a higher standard of living is then presumed to correspond to higher living expenses, *LIV_EXP*) than to the household size by itself. Mishra and El-Osta (2001) noted that one of the primary reasons for an increasing reliance on off-farm income was to increase total income.

Moreover, investments in nonfarm assets (*NF_INVEST*) are also found to have a positive impact on off-farm income reliance, which is consistent with the results reported by Mishra and Morehart (2001). A separate Tobit model was estimated to further disentangle the relationship between the off-farm income share and nonfarm investments (log-likelihood function = -1,271.94; sigma = 0.653; *p*-value of sigma <0.0001). The impact of nonfarm retirement accounts on the off-farm income share was positive (*p*-value = 0.0891), while a negative relationship was found for investments in nonfarm real estate (*p*-value = 0.001). None of the other three nonfarm investment categories were significantly related to the off-farm income share.

In addition, a positive and significant relationship is found between the off-farm income share and farm tenure share (*TENURE_SHARE*). The positive sign for this coefficient is inconsistent with earlier studies based on national (Tavernier, Temel, and Li, 1997) or shorter farm household data sets (Mishra and Goodwin, 1997). One reason for the positive relationship found in the present study is that farm enterprises with a higher tenure share operate with a lower value of the farm capital stock, making the farm operator more likely to seek off-farm work. This finding is further confirmed in the subsequent presentation of the estimates for the farm capital stock equation.

Only farm specialization in crop production (*CROP*) is significantly and positively related to the off-farm income share. Specialized dairy (*DAIRY*) and hog (*HOG*) operations are typically more labor intensive than crop enterprises and, although the coefficients for these farm type specializations are negative (as expected), they are not statistically significant. According to the data, specialization in beef (*BEEF*) production is not related to the dependent variable.

A cautious interpretation of these results is warranted, as the respective number of observations for specialization in dairy, hog, and beef production is very low. Hence, our results are also sensitive to the definition of specialization. By increasing the threshold level to 80% of farm gross sales, the dairy specialization becomes negatively and significantly related to the off-farm income share, but corresponding results for hog and beef specialization do not change.

The relationships between the off-farm income share and the amount of government payment (*GOV_PAY*) or population density (*COUNTY_POP*) are both significant at the 10% level. The sign of the coefficient for government payments is positive, which is partly consistent with work by Shrestha and Findeis (2005). Based on county-level data, they found the effect on other federal programs (OFPs) on off-farm employment to be positive in the Northern Crescent and Eastern Uplands— i.e., opposite of the results for the United States overall. To investigate to what extent the result obtained in this study is due to the passage of the 1996 policy change (through the FAIR Act), the model was reestimated over the 1993–1996 period. No major changes were observed with respect to the coefficient related to government payments.

Finally, and interestingly, the predictive measure of farm financial distress ($z-1$) has a positive and highly significant effect on off-farm income reliance.

Table 3. Ordinary Least Squares for Determinants of Capital Stock by Farm Households in Southwestern Minnesota, 1993–2002

Variable	Coefficient	p-Value
Intercept	5.61	< 0.0001
Off-Farm Income Share (*OFI_SHARE*)	0.025	0.3839
Operator Age (*OP_AGE*)	0.0064	0.0377
Operator Age Squared (*OP_AGE*^{2})	$-0.5 * 10^{-4}$	0.0999
Years in Farming (*FARMING_YRS*)	0.0005	0.6574
Total Acres Operated (*TOT_ACRES*)	0.0005	< 0.0001
Tenure Share (*TENURE_SHARE*)	−0.172	< 0.0001
Crop Dummy (*CROP*)	−0.068	< 0.0001
Dairy Dummy (*DAIRY*)	0.039	0.1544
Hog Dummy (*HOG*)	0.125	< 0.0001
Beef Dummy (*BEEF*)	0.1335	< 0.0001
Operating Profit Margin (*PROF_MARG*)	0.1345	< 0.0001
Asset Turnover Rate (*ASSET_TURNOVER*)	0.649	< 0.0001
Debt-to-Asset Ratio (*DEBT-ASSET*)	0.067	0.0008
Government Payments (*GOV_PAY*)	$0.32 * 10^{-5}$	0.1101
Predictor of Financial Distress, $z - 1$ (*FIN_DISTRESS*)	0.089	< 0.0001
R^2 (Adjusted R^2) = 0.8204 (0.8184)		
F-Value (p-Value) = 396.56 (< 0.0001)		
No. of Observations = 1,318		

Capital Equation

Parameter estimates for the off-farm income share model are reported in Table 3. Yielding an R^2 value of 0.8204, the model explains 82% of the variation in the capital stock in sampled farm operations. The variable of special interest in this study is *OFI_SHARE*, which measures the explanatory power of the off-farm income share to the capital stock. The results, however, suggest that off-farm income reliance does not provide any such explanation. The negative coefficient implies that such reliance reduces farm capital accumulation (i.e., disinvestment). Conversely, a positive relation would have implied that funds earned outside of the farm operation were reinvested in the farm enterprise. It is noted, however, that the predictive measure of financial distress ($z - 1$) is positively related to the capital stocks, suggesting that larger farms (by capital) are more financially vulnerable.

The coefficient of farm size (*TOT_ACRES*) is small but positive, implying that on average, land and capital are complements. In addition, the farm operator age (*OP_AGE*) characteristics reveal a nonlinear but not statistically significant relationship. Note also that the impact of number of years in farming (*FARMING_YRS*) is insignificant as well. *TENURE_SHARE* has a negative and significant effect on farm capital accumulation. This finding is of relevance for the off-farm income model as smaller firms are likely to be more dependent on off-farm income.

Farm specialization has a mixed effect on capital accumulation, depending on farm type. The coefficient for farms specializing in *CROP* production has a negative and significant effect on the capital stock, while the coefficients for specialization in *DAIRY*, *HOG*, and *BEEF* production indicate a positive relationship with capital intensity. The results for *DAIRY* operation, however, are not significant.

Farm capital efficacy measures, as well as leverage, are also significant in explaining capital accumulation. The asset turnover rate (*ASSET_TURNOVER*) is negatively related to the stock of capital. Our interpretation of this finding is that a farm operation with a higher asset turnover rate has a lower volume of capital. On the other hand, there is a positive relationship between the operating profit margin (*PROF_MARG*) and the stock of capital, which suggests larger farm operations are more efficient in generating profits on their sales.

In addition, our results reveal that a higher debt-to-asset ratio (*DEBT-ASSET*) is associated with a lower capital stock (i.e., farm operations with a lower capital stock are relatively more indebted than farm operations with a larger volume of capital). This result should be considered in relation to the farm operator's age (*OP_AGE*) and the experience of the farm operator (*FARMING_YRS*).

A correlation analysis on our data suggests that leverage is negatively related to farmers' age and experience, but positively related to farmed acreage. Age and experience are in turn negatively associated with the asset turnover rate, and positively associated with the operating profit margin. There is, however, no significant association between age of the farm operator and the farmed acreage, but operator age is positively related to the value of farm assets. In concert, these findings likely suggest that the negative relation observed in Table 3 between the debt-to-asset ratio and the capital stock is due to life-cycle patterns of investment and financing the farm operation.

Finally, as expected, government payments (*GOV_PAY*) are found to be weakly positively related to capital stocks.

Concluding Remarks

Using a censored simultaneous estimation of farm-level data, we evaluate the role of farm operator characteristics; farm household measures; nonfarm investments; farm characteristics; farm capital efficacy; farm financial status; state dependence in off-farm income reliance; and, finally, a local labor market component in off-farm income reliance and capital accumulation. A novel feature of this study is that we jointly investigate the decisions by farm households to work off-farm, and their farm capital accumulation. With the exception of the work by Ahituv and Kimhi (2002), the literature examining off-farm labor supply appears to have overlooked the possible endogeneity of farm capital in off-farm labor decisions, and vice versa. This study has yielded several important results:

- First, the results strongly suggest that there is a negative relation between off-farm income reliance and farm capital accumulation, and that there is no feedback from off-farm income reliance to farm capital accumulation. This finding likely implies many part-time farmers, or farm households operating smaller farm units, to a greater extent rely on off-farm income when compared to full-time operators or larger farm units. Consequently, becoming reliant on off-farm income is associated with a farm asset disinvestment strategy. The connection between off-farm income and farm capital has important policy implications. Agricultural policy affects both rural and urban labor markets, and labor market policy tends to spill over to the farm sector. In addition, encouraging (or impeding) specific forms of agricultural production, such as part-time farming, necessitates an understanding of the causality between off-farm income and farm capital, in particular because policies cannot be easily reversed.

- Second, there is support for true state dependence in off-farm income reliance. As noted by Corsi and Findeis (2000), this finding implies that off-farm labor adjustments will be more rigid than without such dependence, and although farm households might seek off-farm income to counteract farm income volatility, this dependence likely indicates that off-farm income is critical to the financial well-being of many farm households. A related result is that government payments are found to be weakly positively related to off-farm income reliance and strongly positively related to capital intensity. The relationship between government payments and off-farm income reliance supports findings reported by Shrestha and Findeis (2005). Using county-level data, they found that the income effect of government payments is specific to geographic region. Our results are insensitive to the presence of more decoupled payments following the 1996 FAIR Act, corroborating the recent results of Ahearn, El-Osta, and Dewbre (2006) who found that the observed nationwide increase in off-farm labor participation was not the result of changes in government subsidies following the 1996 reform of agricultural policy. We therefore conclude it is not unlikely that a farm household allowed to more flexibly plan its production organization, while still receiving government support, will tend to seek more off-farm work; to a large extent, many farm households depend on off-farm income as a source for their cash income. Yet another related result of our study is that farm households predicted to be in farm financial distress are more likely to rely on off-farm income.

- Third, while an emerging literature has provided results on determinants of off-farm investment, little attention has been given to the role of off-farm investments in explaining off-farm work participation or off-farm income reliance. We find that investments in nonfarm retirement accounts are related to off-farm income reliance. This result is reasonable, as pension plans might be included in off-farm employment contracts. However, it further accentuates the rigidity in off-farm labor adjustments.

- Finally, the estimation of the capital accumulation model suggests that farm financial characteristics such as leverage and financial distress, as well as farm capital efficacy factors such as operating profit margin and asset turnover rate, contribute in explaining farm capital growth—and therefore indirectly have an effect on off-farm income reliance.

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Structural Breaks and Agricultural Asset Allocation

Dustin L. Pendell and Allen M. Featherstone

Abstract

Structural breaks have been found to have large effects on optimal investment allocations. This analysis empirically tests for a structural break and then evaluates the impact the break has on the optimal allocation of agricultural and nonagricultural investments using a mean-variance model. Results indicate nonfarm investors could enhance their portfolios by investing in farm assets. However, the results suggest that the allocation of assets prior to the structural break in the early 1950s is much greater than the time period following the break and the entire 1926–2004 time period. Typically, portfolio research has not tested for structural breaks and this may adversely affect decisions on investment allocation.

Key words: agricultural assets, investment portfolio, mean-variance, structural break

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Investors constantly face the problem of maximizing their wealth subject to their internal risk constraints. Traditionally, many investors do not invest in agricultural assets; rather, they invest in stocks and bonds. Investors may include farm assets in their portfolios if the risk-return characteristics are favorable. If nonfarm investors diversify into agricultural assets, both farm and nonfarm investors could benefit.

One aspect of portfolio selection that has received relatively less attention is the issue of structural instability. Although the parameters of the return model or the "true" model are not known to investors, optimal investment allocation assumes the data-generating process remains constant throughout time. This assumption can have important effects on optimal asset allocation (Pettenuzzo and Timmermann, 2005; Barberis, 2000).

There are many reasons for questioning the assumption that the data-generating process is constant over time. It has been demonstrated that structural changes affect many economic and financial variables (Stock and Watson, 1996). Structural breaks are known to have occurred in samples spanning long periods. Possible explanations for these structural shifts include changes in technology, policy, and economic shocks, such as the oil crisis in the early 1970s, the Great Depression, and World War II.

Most studies use long spans of data in order to obtain regression coefficient estimates. For example, Moss, Featherstone, and Baker (1987) use annual data from 1926 to 1984 to estimate the efficient multiperiod investment portfolio by including stocks, bonds, T-bills, and agricultural assets. The data-generating process is unlikely to have remained constant through a sample spanning the Great Depression, World War II, and the high inflation period of the 70s.

The primary objective of this study is to empirically test for a structural break and, if one exists, examine how it affects the optimal allocation of agricultural assets. Specifically, this research compares optimal agricultural asset allocation before and after a structural break. In addition, this study determines the degree to which agricultural assets enter into the investors' optimal portfolios for multiple-year planning horizons at varying levels of risk aversion, having stocks, bonds, money, and Treasury bills as alternative investments. To accomplish these objectives, we test for a structural break when there is uncertainty about the date of the structural break.

Previous Literature

A considerable body of research has investigated structural break issues (e.g., Barberis, 2000; Bai and Perron, 1998; Bai, Lumsdaine, and Stock, 1998; Bai, 1997; Diebold and Chen, 1996; Andrews, 1993). Pettenuzzo and Timmermann (2005) assessed the predictability of U.S. stock returns and the allocation of assets under structural breaks using data from 1926 to 2003. Their model allowed for uncertainty about the timing of the breaks as well as the number of breaks. Bayesian model averaging techniques were employed to allow for model uncertainty because investors are assumed to not know the true model or its parameter values. Pettenuzzo and Timmermann concluded that breaks have a large effect on the allocation of assets.

Pastor and Stambaugh (2001) examined the equity premium using the equity-return and risk-free return series from January 1834 to June 1999 while allowing for structural breaks. The univariate approach used to estimate equity premiums allows for uncertainty about the timing of the breaks based on priors about the tradeoffs between risk and returns. The authors found the long history of returns contains information about the current equity premium, even if the distribution of returns has experienced structural breaks. Further, they conclude that identifying the most likely dates at which breaks occurred is important in estimating the equity premium.

The importance of examining structural breaks rests on the fact that ignoring such breaks can affect asset allocation decisions. Since the influential study of Markowitz (1952), an extensive literature on optimal asset allocation in finance has emerged. A significant body of recent research has examined issues regarding optimal allocation of assets (e.g., Campbell, Chan, and Viceira, 2003; Brennan and Xia, 2002; Ang and Bekaert, 2002; Brennan, Schwartz, and Lagnado, 1997; Kandel and Stambaugh, 1996). Additionally, several studies have explicitly examined optimal investment portfolios with farm assets as alternative investments (e.g., Hennings, Sherrick, and Barry, 2005; Kaplan, 1985; Lins, Sherrick, and Venigalla, 1992; Webb and Rubens, 1988; Moss, Featherstone, and Baker, 1987).

Hennings, Sherrick, and Barry (2005) studied the impact of farmland investments on the efficient mixed-asset portfolios using government bonds, Treasury bills, common stocks, corporate bonds, Morgan Stanley Capital International equity indices, interest rates, real estate investment trusts, commodity indices, cash rents for cropland, and National Council of Real Estate Investment Fiduciaries farmland indices from 1972 through 2003. Their results demonstrate farmland investments improve the efficiency (i.e., reduction in risk for an equivalent return) of mixed-asset portfolios.

Evaluating the attractiveness of farmland investments in the efficient portfolio, Lins, Sherrick, and Venigalla (1992) examined common stocks, long-term corporate bonds, business real estate, and farmland over the 1967–1988 time period. They found diversification into farmland enhances the efficiency of portfolios for institutional investors. Also, their conclusions were robust to increases in the variance of returns to farm real estate and reductions in annual returns to farm and business real estate.

Webb and Rubens (1988) derived risk-efficient portfolios containing common stocks, corporate bonds, government bonds, small capitalization stocks, residential real estate, and farmland from 1967 through 1986. Using the six alternative assets and alternate tax rates, they concluded substantial portions of the optimal portfolios contained residential and farm real estate. A considerable amount of residential and farm real estate was included in the portfolios even when the variances for real estate were quintupled.

Moss, Featherstone, and Baker (1987) assessed the extent to which agricultural assets enter the risk-efficient portfolio using real rates of returns and a multiperiod investment horizon for common stocks, small capitalization stocks, long-term corporate bonds, long-term U.S. government bonds, U.S. Treasury bills, money, borrowing at the prime interest rate, and farm assets over the period 1926–1984. Agricultural assets were found to enter the risk-efficient portfolios at greater levels than historically observed in the capital market. Moreover, their conclusions were robust to increases in the variance of rate of return to agricultural assets.

Using data from 1947–1980, Kaplan (1985) examined investment portfolios using six alternative investments including farm real estate, large and small capitalization stocks, long-term corporate and government bonds, and Treasury bills. Because farmland had a low coefficient of variation and low correlations with other assets, farmland investment was shown to be highly attractive.

Our investigation adds to the work of earlier studies in two important ways. First (aside from Hennings, Sherrick, and Barry, 2005), all of the previous studies examining portfolios containing agricultural assets have used data that are more than 15 years old. Second, previous studies have not tested for a potential structural break and, if one exists, the impact it has on investment portfolios with agricultural assets as an investment option.

Theory and Methods

The expected utility hypothesis is often used as the basis for making choices under risk. Decision makers will select an optimal portfolio from investments with risky outcomes to maximize their expected utility. An equivalent form of the expected utility hypothesis under certain assumptions is mean-variance analysis.

The mean-variance method (or EV method) developed by Markowitz (1952) is an efficiency criterion based on the concept of expected utility maximization. Pulley (1981) shows that a generalized Von Neumann-Morgenstern utility function and the linear mean-variance model are equivalent. Further, maximizing expected utility is equivalent to the linear EV method for determining optimal investment portfolios if the returns are normally distributed and the utility function is assumed to be negative exponential (Freund, 1956).

Featherstone and Moss (1990) show that the linear mean-variance model maximizes the certainty equivalent under either Freund's or Pulley's assumptions. However, critics argue the results from the EV model are often questionable due to a violation of those assumptions.

Several earlier studies have examined these issues. For example, Tsiang (1972) argues this approach is appropriate for analyzing investment behavior for small risk-takers. Tew, Reid, and Witt (1991); Reid and Tew (1987); Kroll, Levy, and

Markowitz (1984); and Levy and Markowitz (1979) have shown both theoretically and empirically that the linear EV methods and the expected utility approach produce nearly identical optimal portfolios. Turvey, Escalante, and Nganje (2005); Collins and Gbur (1991); Featherstone et al. (1988); and Turvey and Driver (1986) have also discussed the equivalence between the EV and expected utility-maximization approaches.

This study adopts the EV framework to generate a set of allocations of investments such that the portfolios are on the risk-efficient frontier. The risk-efficient frontier is a set of portfolios having the maximum return for every given level of risk. The optimal investment portfolios are chosen whereby:

$$(1)\quad \underset{\mathbf{X}}{\text{Max}}\; z = \mathbf{C}'\mathbf{X} - \frac{\lambda}{2}\mathbf{X}'\mathbf{\Omega}\mathbf{X},$$

subject to:

$$(2)\quad \sum_{j} x_{1j} = 100$$

and

$$(3)\quad x_{1j} = x_{2j} = \ldots = x_{nj}\ \ \forall j,$$

where n refers to length of the planning horizon or the time period for which a portfolio is held; a denotes the alternative investments; $\mathbf{C}$ is a vector, $n(a) \times 1$, of the expected continuous time rates of returns; $\mathbf{X}$ is an $n(a) \times 1$ vector of the investment percentages; λ is the Arrow-Pratt risk-aversion coefficient (measure of relative risk aversion); and $\mathbf{\Omega}$ is an $na \times na$ matrix of variances and covariances of the rates of returns.[1]

Equation (1) expresses the EV method as described above. Equation (2) requires the amount invested sum to 100%, while equation (3) implies the percentage invested in each investment is constant throughout the planning horizon. Equation (3) assumes investors have a buy-and-hold strategy (Moss, Featherstone, and Baker, 1987). Nonnegativity was imposed on all assets with the exception of borrowing, which was constrained to be nonpositive.

The average expected continuous time rates of returns ($\mathbf{C}$) and the variance-covariance structures of the rates of returns ($\mathbf{\Omega}$) must be estimated before applying the EV method. The methods and procedures to estimate the returns and the variance-covariance structure for the EV model for multiple assets with both single and multiple holding periods follow those advanced by Moss, Featherstone, and Baker (1987). This method allows for cross-period correlation due to economic cycles that appear in some asset classes.

If the expected continuous time rates of returns are constant across the years for the assets, then the average return is calculated by multiplying the n-year holding period by the sum of the single-period return [equation (4)]; if the returns are not constant over time, the average return over an n-year holding period is calculated by summing the expected continuous time rates of returns across the assets and years [equation 5)]:

$$(4)\quad \mathbf{C}'\mathbf{X} = n\sum_{j=1}^{a} c_j x_j,$$

$$(5)\quad \mathbf{C}'\mathbf{X} = \sum_{i=1}^{n}\sum_{j=1}^{a} c_{ij} x_{ij},$$

where c and x are elements in $\mathbf{C}$ and $\mathbf{X}$, respectively.

Equation (6) calculates the variance for an n-year return with possible dependence of the returns across years:

$$(6)\quad \mathbf{X}'\mathbf{\Omega}\mathbf{X} = \left(\sum_{i=1}^{n}\left[\sum_{j=1}^{a} x_{ij}^2 \mathrm{Var}(X_{ij}) + \sum_{j=1}^{a}\sum_{\substack{k=1\\ j\neq k}}^{a} x_{ij}x_{ik}\mathrm{Cov}(x_{ij}, x_{ik})\right]\right) + \sum_{j=1}^{a}\sum_{\substack{i=1}}^{n}\sum_{\substack{h=1\\ i\neq h}}^{n} x_{ij}x_{hj}\mathrm{Cov}(x_{ij}, x_{hj}).$$

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[1] For more discussion on Arrow-Pratt risk-aversion coefficients, see Featherstone et al. (1988) and Pulley (1981).

If the correlations of the returns for the investments are independent across the years and the within-year variance-covariance matrix is the same for each year, the variance of return is given by:

$$(7)\quad \mathbf{X'\Omega X} = n\left[\sum_{j=1}^{a} x_j^2 \mathrm{Var}(X_j) + \sum_{j=1}^{a}\sum_{\substack{k=1\\ j\neq k}}^{a} x_j x_k \mathrm{Cov}(x_j, x_k)\right].$$

To calculate a single-year optimal portfolio, the returns given by equation (4) and the variance given by equation (7) would be divided by *n*.

After estimating the average returns and the variance-covariance structures, optimal portfolios are generated by varying the Arrow-Pratt relative risk-aversion coefficient (λ). Finally, the optimal portfolios are evaluated to examine whether investors would invest in agricultural assets, to what degree for the single- and multiple-year holdings, and whether the investment mix is the same before and after the structural break.

Data

For this study, we use real returns from eight investments spanning from 1926 through 2004: large company stocks, small company stocks, long-term corporate bonds, long-term U.S. government bonds, U.S. Treasury bills, agricultural assets, money, and the prime interest rate. Data for the first five investments are derived from Ibbotson Associates, Inc. (2004). Data for agricultural assets are from the *Agricultural Income and Finance Outlook* report published by the U.S. Department of Agriculture's Economic Research Service (USDA/ERS, 2006). The money data come from the U.S. Department of Commerce's Bureau of Economic Analysis (BEA) (2006), and the prime interest rate data are taken from the Board of Governors of the Federal Reserve System (2006).

Large company stock returns are represented by Standard & Poor's Composite Index which includes 500 of the largest stock companies in the United States since March 1957 (prior to March 1957 it consisted of the 90 largest stock companies). Small company stock returns are based on the smallest 20% of companies traded on the New York Stock Exchange. Long-term corporate bonds are calculated by using capital appreciation and income returns from the Salomon Brothers Long-Term High-Grade Corporate Bond Index. Long-term U.S. government bonds are calculated from the returns including a current coupon with a term near 20 years. Returns from U.S. Treasury bills are the returns from a one-month holding period for the shortest-term bill having not less than one month to maturity. Additional information can be obtained through Ibbotson Associates, Inc. (2004).

Returns to agricultural assets are calculated by summing the rate of returns to farm assets from current income and real capital gains on farm assets. The rate of returns to farm assets from current income is calculated by taking the returns to agricultural assets from current income divided by agricultural assets, while the real capital gains are determined by taking the real capital gains on agricultural assets divided by agricultural assets (USDA/ERS, 2006).

The prime interest rate is included to allow investors to leverage their portfolios.[2] The return to money is negative of the inflation rate. The inflation rate is the personal consumption expenditures portion of the implicit gross domestic product deflator which is used in deflating all return series data. All of the return data were converted from effective annual to continuous time by taking the natural logarithm of one plus the effective annual rate (i.e., real rate of return = nominal rate of return minus inflation rate) to remove money illusion.[3]

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[2] The portfolios are also reestimated without allowing for borrowing.

[3] This study does not assume real risk-free assets; therefore, Tobin's separation theorem does not apply (Moss, Featherstone, and Baker, 1987).

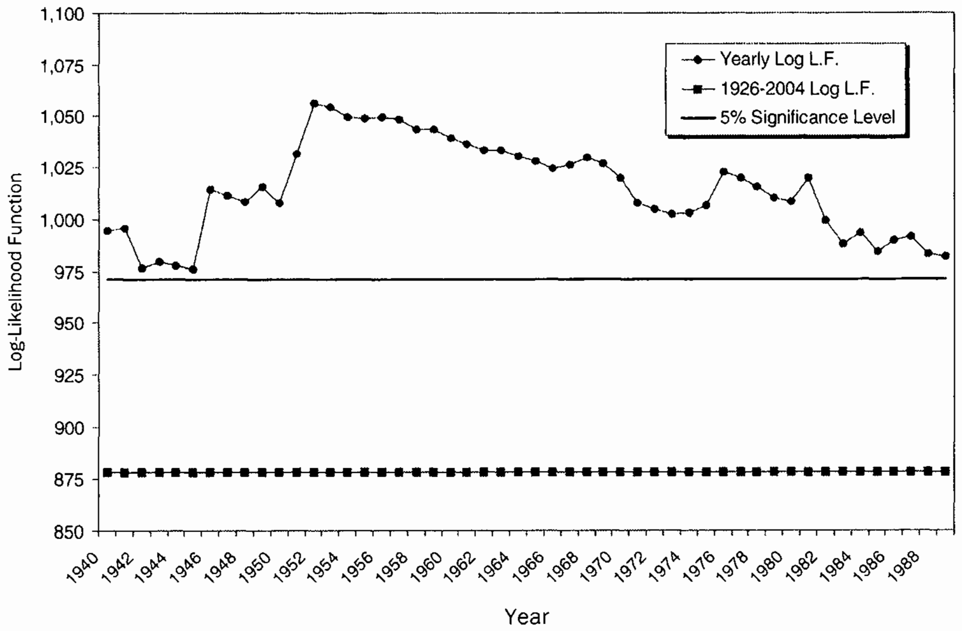

Figure 1. Log-Likelihood Values to Determine the Maximum Likelihood for a Structural Break, 1940–1990

Empirical Estimation of the Structural Break

To determine if a structural break occurred, and if so, during which year, this study uses a multivariate first-order autoregressive model. Ordinary least squares (OLS) regressions were used to estimate each asset's rate of return as a function of the remaining seven assets' previous year's returns. Durbin-Watson statistics confirmed that no autocorrelation remained after correcting for first-order autocorrelation at the 1% significance level. One method for determining a structural break without making any prior assumptions about the date of the break is through a Bayesian switching regression framework.

The first step in testing for an unknown structural break is to model the first-order autoregressive process for each of the eight alternative investments using the first 15 years of data (i.e., estimate the OLS models using return data from 1926–1940 for each of the eight alternative investments).[4] Second, after estimating the eight OLS models, the log-likelihood functions for each model were estimated. Next, all eight OLS models were then reestimated using the remaining data (i.e., reestimate the OLS models using data from 1941–2004). Fourth, the log-likelihood functions for all eight reestimated equations were obtained. All 16 log-likelihood values (i.e., log-likelihood values from the OLS models using data from 1926–1940 and 1941–2004) were then summed and termed "year log likelihood" (i.e., the sum of the 16 log-likelihood functions using data from 1926–1940 and 1941–2004 was termed "1940 log likelihood").

This process of estimating the 16 equations was repeated using data from one additional year for the first eight equations (i.e., estimate the OLS models

[4] An assumption that the structural break did not occur within the first 15 years or the last 15 years (i.e., the structural break occurred between 1940 and 1989) was used in implementing this procedure to allow for sufficient degrees of freedom for estimation.

using return data from 1926–1941 for each of the eight alternative investments) and one less year's data for the second set of eight equations (i.e., reestimate the equations using data from 1942–2004 for each of the eight alternative investments) and termed "1941 log likelihood." This process was repeated until the data from 1926–1989 and 1990–2004 were used (i.e., "1989 log likelihood").

After the year log-likelihood functions were estimated, the date of a structural break was determined by the year that maximized the log-likelihood functions. In this study, the highest support for a structural break occurred in the year 1952 (Figure 1). The upper graph line represents the yearly log-likelihood function. The center, solid graph line represents the critical log-likelihood level for the 95% confidence level. All of the yearly log-likelihood functions are statistically significant at the 5% level based on a χ^2 value with 72 degrees of freedom.

Empirical Estimation of the Expectations Model

A multivariate first-order autoregressive model was used to estimate the means and the variance-covariance matrix for three time periods: 1926–2004, 1926–1952, and 1953–2004. The regression results are presented in Tables 1–3.

Table 4 provides summary statistics of the real rates of returns for the eight investments over the three time periods. The means and standard deviations are similar to those reported by Moss, Featherstone, and Baker (1987) with two exceptions: the mean return for government bonds in this study is 2.51% compared to Moss, Featherstone, and Baker's 0.55%, and our standard deviation for the prime interest rate is 4.44% compared to 20.74% in their study.

With the following exceptions, the average mean and standard deviation for the rates of return for all three time periods are similar: first, the mean return to Treasury bills is negative during the 1926–1952 time span and positive for the 1953–2004 and 1926–2004 time periods; second, the standard deviation for small company stocks during 1926–1952 is approximately one and one-half and two times larger than the corresponding values for 1926–2004 and 1953–2004.

As reported in Table 4, the mean rate of return on agricultural assets from 1926–2004 was 4.34%, which is higher than long-term corporate bonds (2.96%) and long-term government bonds (2.51%), but less than large company stock (6.65%) and small company stock (9.20%) returns. However, agricultural assets are less variable than all four of those alternative investments. Returns to agricultural assets for 1926–1952 was 5.12%, making it the third highest investment return (stock returns were higher) and the least variable of all eight investments. From 1953–2004, agricultural assets returns were higher than corporate and government bonds, Treasury bills, and money, while being less variable than stocks and bonds.

The contemporaneous correlations among the real rates of returns for the assets are reported in Tables 5–7. During 1926–2004, agricultural assets had a negative correlation with all of the investment types except for large and small company stocks (Table 5). The correlation results for 1926–1952 are similar to the entire time period, except farm assets had a positive correlation with corporate bonds and a negative correlation with large company stocks (Table 6). Agricultural assets exhibit positive correlation with all of the assets except for the prime interest rate and small company stocks during the 1953–2004 time period (Table 7).

The weak negative correlation between farm assets and the other non-stock assets (1926–2004), combined with large variances for large and small company stocks, makes agricultural assets a potential source for portfolio diversification. The moderately strong negative correlations of farm assets with large company stocks, money, prime

Table 1. Regression Coefficients and Statistics for Asset Rate of Returns Equations, 1926–2004

		Variables Lagged One Period									
Variables	**Intercept**	**Corporate Bonds**	**Corporate Stocks**	**Agricul. Assets**	**Gov't. Bonds**	**Money**	**Prime Interest**	**Small Stocks**	**Treasury Bills**	R^2	***F*-Value**
Corporate Bonds	0.0198 (0.0736)	0.6139 (0.3040)	-0.0240 (0.0744)	-0.5614 (0.2045)	-0.6561 (0.2845)	-0.0087 (0.0794)	0.2045 (1.1570)	-0.0485 (0.0470)	-1.5064 (1.2470)	36.46	5.020***
Corporate Stocks	0.0699 (0.1915)	-0.2167 (0.7910)	0.2298 (0.1936)	-0.7377 (0.5321)	0.3591 (0.7405)	-0.0081 (0.2065)	1.8731 (3.0100)	-0.0981 (0.1223)	-3.0669 (3.2450)	7.05	0.663
Agricul. Assets	0.0170 (0.0395)	-0.2548 (0.1630)	-0.0374 (0.0399)	0.5433 (0.1097)	0.4184 (0.1526)	0.0144 (0.0426)	-0.5471 (0.6203)	0.0353 (0.0252)	0.2054 (0.6689)	46.19	7.511***
Gov't. Bonds	0.0241 (0.0793)	0.8852 (0.3274)	0.0443 (0.0802)	-0.5668 (0.2202)	-1.0356 (0.3065)	-0.0186 (0.0855)	2.0495 (1.2460)	-0.0726 (0.0506)	-1.4528 (1.3430)	35.50	4.815***
Money	0.9283 (0.0312)	0.3550 (0.1286)	0.0358 (0.0315)	-0.0461 (0.0865)	-0.2534 (0.1204)	0.0570 (0.0336)	-0.6518 (0.4895)	-0.0601 (0.0199)	0.9788 (0.5278)	43.25	6.668***
Prime Interest	0.0184 (0.0256)	0.2011 (0.1056)	0.0718 (0.0259)	-0.0287 (0.0711)	-0.2652 (0.0989)	-0.0243 (0.0276)	1.5984 (0.4020)	-0.0762 (0.0163)	-0.9068 (0.4334)	68.90	19.381***
Small Stocks	-0.0604 (0.2913)	-0.6463 (1.2030)	-0.4888 (0.2946)	-0.4361 (0.8095)	1.1169 (1.1260)	-0.0960 (0.3142)	4.4550 (4.5780)	0.2894 (0.1861)	-5.8690 (4.9370)	10.59	1.036
Treasury Bills	-0.0006 (0.0251)	0.2273 (0.1038)	0.0750 (0.0254)	-0.0467 (0.0698)	-0.2804 (0.0972)	-0.0096 (0.0271)	0.8359 (0.3950)	-0.0718 (0.0161)	-0.1954 (0.4260)	64.15	15.660***

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. Numbers in parentheses are standard errors.

Table 2. Regression Coefficients and Statistics for Asset Rate of Returns Equations, 1926–1952

		Variables Lagged One Period									
Variables	**Intercept**	**Corporate Bonds**	**Corporate Stocks**	**Agricul. Assets**	**Gov't. Bonds**	**Money**	**Prime Interest**	**Small Stocks**	**Treasury Bills**	R^2	***F*-Value**
Corporate Bonds	0.0124 (0.4446)	0.9681 (0.5066)	0.0029 (0.1322)	-0.3098 (0.4160)	-0.6896 (0.4418)	-1.1568 (1.4580)	0.8516 (2.2890)	-0.0499 (0.0705)	0.5147 (2.9070)	62.66	3.776***
Corporate Stocks	-0.0122 (0.2106)	1.9751 (2.4000)	0.4909 (0.6261)	-0.0207 (1.9710)	-1.1232 (2.0930)	1.1902 (6.9090)	2.2433 (10.8500)	-0.2364 (0.3338)	-5.1395 (13.7700)	8.33	0.204
Agricul. Assets	0.0289 (0.0344)	-0.0413 (0.3924)	0.0181 (0.1024)	0.0987 (0.3223)	0.4496 (0.3422)	-0.6556 (1.1300)	-0.2517 (1.7730)	0.0391 (0.0546)	0.1544 (2.2520)	49.60	2.214*
Gov't. Bonds	0.0321 (0.5532)	0.9865 (0.6304)	0.0459 (0.1644)	-0.2926 (0.5177)	-1.0561 (0.5497)	0.0129 (1.8150)	0.3266 (2.8490)	-0.0758 (0.0877)	0.2861 (3.6170)	50.21	2.269*
Money	-0.0382 (0.0296)	0.5633 (0.3374)	0.0686 (0.0880)	-0.1080 (0.2771)	-0.4060 (0.2943)	-0.8018 (0.9713)	1.1858 (1.5250)	-0.0890 (0.0469)	-0.1757 (1.9360)	69.86	5.215***
Prime Interest	-0.0058 (0.0305)	0.4996 (0.3474)	0.0653 (0.0906)	-0.2075 (0.2853)	-0.4556 (0.3030)	-1.6040 (1.0000)	0.8381 (1.5700)	-0.0815 (0.0483)	1.1278 (1.9930)	75.93	7.099***
Small Stocks	-0.2414 (0.3421)	1.0535 (3.8980)	0.1871 (1.0170)	1.0970 (3.2010)	1.6501 (3.3990)	8.9948 (11.2200)	17.2800 (17.6100)	-0.1901 (0.5420)	-29.4270 (22.3600)	19.25	0.536
Treasury Bills	-0.0193 (0.0302)	0.5153 (0.3436)	0.0793 (0.0896)	-0.2018 (0.2822)	-0.4749 (0.2997)	-1.5238 (0.9892)	0.6487 (1.5530)	-0.0813 (0.0478)	1.2037 (1.9720)	73.65	6.288***

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. Numbers in parentheses are standard errors.

Table 3. Regression Coefficients and Statistics for Asset Rate of Returns Equations, 1953–2004

		Variables Lagged One Period									
Variables	**Intercept**	**Corporate Bonds**	**Corporate Stocks**	**Agricul. Assets**	**Gov't. Bonds**	**Money**	**Prime Interest**	**Small Stocks**	**Treasury Bills**	R^2	***F*-Value**
Corporate Bonds	0.0072 (0.0368)	0.6415 (0.4281)	-0.0762 (0.1168)	-0.7881 (0.2814)	-0.7751 (0.4040)	0.6346 (0.5591)	3.6086 (1.5300)	-0.0510 (0.0860)	-3.1067 (1.9760)	38.16	3.315***
Corporate Stocks	0.1292 (0.0725)	-0.7392 (0.8447)	0.2367 (0.2304)	-1.4300 (0.5552)	0.7197 (0.7972)	-6.4326 (3.9000)	3.6980 (3.0200)	-0.2162 (0.1696)	1.0303 (1.1030)	21.34	1.459
Agricul. Assets	0.0444 (0.0150)	-0.1692 (0.1752)	0.0194 (0.0478)	0.4610 (0.1151)	0.2783 (0.1653)	0.3694 (0.2288)	0.6520 (0.6263)	-0.0418 (0.0352)	-2.1999 (0.8087)	65.28	10.105***
Gov't. Bonds	0.0003 (0.0387)	0.9894 (0.4511)	-0.0450 (0.1230)	-0.7062 (0.2965)	-1.2167 (0.4257)	0.7468 (0.5892)	3.5037 (1.6130)	-0.0648 (0.0906)	-2.4773 (2.0820)	39.55	3.517***
Money	-0.0078 (0.0041)	0.0563 (0.0481)	0.0031 (0.0131)	-0.0977 (0.0316)	-0.0292 (0.0454)	0.8789 (0.0628)	0.3565 (0.1718)	0.0004 (0.0097)	-0.5042 (0.2218)	87.26	36.831***
Prime Interest	0.0001 (0.0048)	0.0146 (0.0556)	0.0244 (0.0152)	0.0032 (0.0365)	-0.0592 (0.0524)	-0.0639 (0.0726)	0.9199 (0.1986)	0.0022 (0.0112)	-0.0059 (0.2565)	82.37	25.120***
Small Stocks	0.0986 (0.1015)	-0.3076 (1.1820)	-0.4321 (0.3224)	-0.7676 (0.7767)	0.5848 (1.1150)	0.6402 (1.5440)	5.1029 (4.2250)	0.1381 (0.2373)	-8.1366 (5.4560)	14.22	0.891
Treasury Bills	-0.0055 (0.0045)	0.0368 (0.0519)	0.0321 (0.0142)	-0.0174 (0.0341)	-0.0700 (0.0490)	-0.0609 (0.0678)	0.2060 (0.1855)	0.0032 (0.0104)	0.6160 (0.2396)	78.23	19.313***

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively. Numbers in parentheses are standard errors.

Table 4. Summary Statistics of One-Year Real Return for Assets (percent)

Variables	Mean	Std. Deviation	Minimum	Maximum
		— 1926-2004 —		
Corporate Bonds	2.96	8.94	-13.39	29.36
Corporate Stocks	6.65	19.25	-47.42	41.72
Agricultural Assets	4.34	5.21	-11.21	18.09
Government Bonds	2.51	9.56	-13.54	27.81
Money	-2.79	4.01	-12.03	11.76
Prime Rate	2.88	4.44	-9.87	16.07
Small Stocks	9.20	29.85	-91.07	91.42
Treasury Bills	0.86	4.07	-11.68	12.71
		— 1926-1952 —		
Corporate Bonds	3.00	7.85	-13.25	22.03
Corporate Stocks	5.54	23.73	-47.42	41.72
Agricultural Assets	5.12	5.23	-8.37	13.79
Government Bonds	2.23	8.46	-13.54	27.32
Money	-1.33	5.82	-12.03	11.76
Prime Rate	1.34	6.70	-9.87	16.07
Small Stocks	7.06	41.06	-91.07	91.42
Treasury Bills	-0.28	6.34	-11.68	12.71
		— 1953-2004 —		
Corporate Bonds	2.94	9.54	-13.39	29.36
Corporate Stocks	7.37	16.56	-39.76	41.31
Agricultural Assets	3.83	5.23	-11.21	18.09
Government Bonds	2.59	10.08	-13.09	27.81
Money	-3.52	2.35	-9.44	-0.97
Prime Rate	3.63	2.32	-1.46	8.30
Small Stocks	10.13	22.18	-42.55	57.65
Treasury Bills	1.42	1.94	-3.81	5.64

interest rate, government bonds, and T-bills, coupled with farm assets having the third largest return and the smallest variance, identify farm assets as an excellent source of diversification during the 1926–1952 period. Although farm assets have weak positive correlation with all of the investments from 1953–2004, except for the prime interest rate and small company stocks, agricultural assets have the potential for entry into the optimal portfolio because this investment category has the third largest return and the fourth smallest variance.

The rates of returns for the multiple-year models are the same as for the single-year model because of the initial conditions (Moss, Featherstone, and Baker, 1987). The variance-covariance matrix for the single-year model is calculated from the OLS regression residuals, while the variance-covariance matrix for the multiple-year models is determined using the OLS regression coefficients and residuals. For derivations on how the variance-covariance matrix is calculated for single- and multiple-year models, interested readers are referred to Moss, Featherstone, and Baker (1987).

Table 5. Contemporaneous Correlations Among Real Rates of Return, 1926–2004

	Corporate Bonds	Corporate Stocks	Agricul. Assets	Gov't. Bonds	Money	Prime Rate	Small Stocks	Treasury Bills
Corporate Bonds	1	0.2791 [2.53]*	0.0026 [0.02]	0.9342 [22.84]*	0.4025 [3.83]*	0.1928 [1.71]	0.1322 [1.16]	0.2140 [1.91]
Corporate Stocks		1	0.2599 [2.35]*	0.2520 [2.27]*	0.2257 [2.02]*	0.2248 [2.01]*	0.8095 [12.02]*	0.2448 [2.20]*
Agricul. Assets			1	-0.0290 [0.25]	-0.0156 [0.14]	-0.1830 [1.62]	0.2360 [2.12]*	0.1523 [1.34]
Gov't. Bonds				1	0.3753 [3.53]*	0.2276 [2.04]*	0.0934 [0.82]	0.2254 [2.02]*
Money					1	0.6493 [7.44]*	0.1547 [1.37]	0.6719 [7.91]*
Prime Rate						1	0.0946 [0.83]	0.9832 [46.98]*
Small Stocks							1	0.1128 [0.99]
Treasury Bills								1

Notes: Numbers in brackets are *t*-values, where an asterisk (*) denotes statistical significance at the 5% level.

Table 6. Contemporaneous Correlations Among Real Rates of Return, 1926–1952

	Corporate Bonds	Corporate Stocks	Agricul. Assets	Gov't. Bonds	Money	Prime Rate	Small Stocks	Treasury Bills
Corporate Bonds	1	0.4652 [2.57]*	0.4629 [2.56]*	0.4714 [2.62]*	0.3582 [1.88]	0.3632 [1.91]	0.8867 [9.40]*	0.4084 [2.19]*
Corporate Stocks		1	-0.2406 [1.21]	0.9099 [10.74]*	0.7859 [6.23]*	0.7493 [5.54]*	0.4332 [2.35]*	0.7657 [5.83]*
Agricul. Assets			1	0.1950 [0.97]	-0.2432 [1.23]	0.2260 [1.14]	0.4350 [2.37]*	0.1877 [0.94]
Gov't. Bonds				1	0.7882 [6.27]*	0.7751 [6.01]*	0.3921 [2.09]*	0.7855 [6.22]*
Money					1	0.9943 [45.89]*	0.2819 [1.44]	0.9915 [37.44]*
Prime Rate						1	0.2496 [1.26]	0.9950 [48.91]*
Small Stocks							1	0.2832 [1.45]
Treasury Bills								1

Notes: Numbers in brackets are *t*-values, where an asterisk (*) denotes statistical significance at the 5% level.

Table 7. Contemporaneous Correlations Among Real Rates of Return, 1953–2004

	Corporate Bonds	Corporate Stocks	Agricul. Assets	Gov't. Bonds	Money	Prime Rate	Small Stocks	Treasury Bills
Corporate Bonds	1	0.1831 [1.32]	0.1394 [1.00]	0.1265 [0.90]	0.3330 [2.50]*	0.1901 [1.37]	0.7993 [9.41]*	0.1527 [1.09]
Corporate Stocks		1	0.1184 [0.84]	0.9477 [21.00]*	0.5740 [4.96]*	0.1003 [0.71]	0.0097 [0.07]	0.0426 [0.30]
Agricul. Assets			1	0.1305 [0.93]	0.0063 [0.04]	0.0448 [0.32]	0.0305 [0.22]	0.0065 [0.05]
Gov't. Bonds				1	0.4684 [3.75]*	0.0424 [0.30]	0.0594 [0.42]	0.0647 [0.46]
Money					1	0.2118 [1.53]	0.2885 [2.13]*	0.2951 [2.18]*
Prime Rate						1	0.0386 [0.27]	0.8608 [11.96]*
Small Stocks							1	0.0099 [0.07]
Treasury Bills								1

Notes: Numbers in brackets are *t*-values, where an asterisk (*) denotes statistical significance at the 5% level.

Results

After determining the structural break date, the EV model was used to estimate the optimal portfolios over a range of relative risk-aversion coefficients (RACs). The relative RACs were decreased until portfolios contained borrowing for a one-year holding period during 1926–2004, though we did not allow portfolios with more than 30% debt.[5] Tables 8–10 present the optimal investment allocations at selected risk-aversion levels for the one-, five-, and ten-year planning horizons for the three time periods studied.

First, we considered the optimal investment portfolios for an investor using the 1926–2004 data (Table 8). The estimated portfolios for this research contain a larger percentage of agricultural assets (18% to 86%) compared to Moss, Featherstone, and Baker's (1987) study which concluded the optimal portfolio should contain 32% to 62% farm assets.

Although the following studies did not allow for investor borrowing, Ibbotson and Fall (1979) report farm real estate comprised 9% to 22% of the portfolio over the period 1947–1978, while Lins, Sherrick, and Venigalla (1992) and Hennings, Sherrick, and Barry (2005)—who studied the respective time periods of 1967–1988 and 1969–2003—suggest investors should allocate between 0% to 100% and 10% to 25% to farm real estate assets, respectively.

Table 9 reports the optimal investment portfolios for the time period prior to the structural break (1926–1952), and Table 10 reports the optimal portfolios following the break date (1953–2004). The optimal portfolios for these two time horizons reflect some notable differences. The optimal percentage

[5] A relative risk-aversion coefficient mean estimate of 5.4 was estimated for Kansas farmers by Saha, Shumway, and Talpaz (1994). A coefficient of between 1.96 and 7.02 was estimated using data on 2,100 U.S. households by Friend and Blume (1975), and a coefficient of between 0.59 and 16.8 was estimated by Blake (1996) using British data.

Table 8. Optimal Portfolios at Selected Risk-Aversion Levels (percent of total assets), 1926–2004

λ[a]	Expected Income[b]	Standard Deviation	Corporate Bonds	Corporate Stocks	Agricul. Assets	Gov't. Bonds	Money	Prime Rate	Small Stocks	Treasury Bills
				— One-Year Holding —						
1.0	6.5	13.5	0	15.4	85.6	0	0	-30.0	29.0	0
2.0	5.2	8.7	2.2	12.0	68.5	3.8	0	0	13.5	0
3.5	4.4	6.8	1.6	6.5	58.1	25.4	0	0	8.4	0
5.5	3.5	5.1	1.2	3.0	44.6	23.9	0	0	6.0	21.3
8.0	2.8	3.9	0.8	0.6	33.5	17.8	0	0	4.7	42.6
11.0	2.3	3.2	0.7	0	26.9	13.8	0	0	3.5	55.1
14.5	2.0	2.9	0.5	0	22.6	11.1	0	0	2.5	63.3
16.5	1.9	2.7	0.5	0	20.9	10.1	0	0	2.1	66.4
21.0	1.8	2.6	0.4	0	18.4	8.5	0	0	1.5	71.2
				— Five-Year Holding —						
1.0	68.5	46.2	0	0	37.6	0	0	-100.0	162.4	0
2.0	50.5	28.2	0	22.8	99.4	0	0	-100.0	77.8	0
3.5	38.4	18.5	0	24.1	87.0	0	0	-52.6	41.5	0
5.5	29.9	12.0	0	14.4	58.7	0	0	0	26.9	0
8.0	27.2	10.2	2.8	16.3	60.6	3.3	0	0	17.0	0
11.0	24.3	8.5	2.3	11.8	53.9	19.1	0	0	12.9	0
14.5	22.4	7.6	2.0	8.9	49.6	29.3	0	0	10.2	0
16.5	21.7	7.2	1.8	7.8	47.9	33.2	0	0	9.3	0
21.0	18.8	6.1	1.5	5.4	40.8	30.4	0	0	7.7	14.2
				— Ten-Year Holding —						
1.0	155.1	56.3	0	0	0	0	0	-100.0	200.0	0
2.0	136.7	46.1	0	0	37.9	0	0	-100.0	162.1	0
3.5	106.2	30.5	0	16.7	92.0	0	0	-100.0	91.3	0
5.5	89.8	23.5	0	31.8	109.2	0	0	-93.3	52.3	0
8.0	71.0	16.3	0	20.7	77.3	0	0	-34.5	36.5	0
11.0	59.8	12.0	0	14.4	58.7	0	0	0	26.9	0
14.5	52.9	9.5	20.6	8.6	49.4	0	0	0	21.4	0
16.5	49.8	8.3	31.7	5.0	43.6	0	0	0	19.7	0
21.0	44.9	6.6	48.4	0	34.8	0	0	0	16.8	0

[a] Risk-aversion coefficient from equation (1).
[b] Total returns (percent).

Table 9. Optimal Portfolios at Selected Risk-Aversion Levels (percent of total assets), 1926–1952

λ [a]	Expected Income [b]	Standard Deviation	Corporate Bonds	Corporate Stocks	Agricul. Assets	Gov't. Bonds	Money	Prime Rate	Small Stocks	Treasury Bills
				— One-Year Holding —						
1.0	8.6	13.8	21.1	9.1	166.3	0	0	-100.0	3.5	0
2.0	7.0	8.4	91.6	1.7	106.7	0	0	-100.0	0	0
3.5	6.4	6.9	119.3	0	80.7	0	0	-100.0	0	0
5.5	6.1	6.4	132.0	0	68.0	0	0	-100.0	0	0
8.0	5.2	5.4	107.9	0	55.7	0	0	-63.6	0	0
11.0	4.3	4.4	76.9	0	45.5	0	0	-22.4	0	0
14.5	3.8	3.9	60.4	0	39.6	0	0	0	0	0
16.5	3.8	3.8	61.5	0	38.5	0	0	0	0	0
21.0	3.8	3.8	63.0	0	37.0	0	0	0	0	0
				— Five-Year Holding —						
1.0	47.4	21.5	0	0	169.7	0	0	-100.0	30.3	0
2.0	47.1	21.0	0	1.1	172.5	0	0	-100.0	26.4	0
3.5	42.4	16.8	28.6	19.4	146.4	0	0	-100.0	5.6	0
5.5	36.1	11.6	81.8	13.2	104.6	0	0	-100.0	0.4	0
8.0	32.8	9.2	111.9	6.2	81.9	0	0	-100.0	0	0
11.0	30.8	7.9	129.9	1.7	68.4	0	0	-100.0	0	0
14.5	29.6	7.3	140.5	0	59.5	0	0	-100.0	0	0
16.5	29.3	7.1	144.0	0	56.0	0	0	-100.0	0	0
21.0	28.7	6.9	149.4	0	50.6	0	0	-100.0	0	0
				— Ten-Year Holding —						
1.0	100.3	26.9	0	0	141.9	0	0	-100.0	58.1	0
2.0	97.9	24.1	0	0	154.4	0	0	-100.0	45.6	0
3.5	94.7	21.4	0	0	170.4	0	0	-100.0	29.6	0
5.5	91.9	19.9	0	19.6	169.5	0	0	-100.0	10.9	0
8.0	80.5	15.0	46.9	17.3	132.0	0	0	-100.0	3.8	0
11.0	72.3	11.6	81.8	13.3	104.6	0	0	-100.0	0.3	0
14.5	67.1	9.7	105.0	7.9	87.1	0	0	-100.0	0	0
16.5	65.1	9.0	113.9	5.7	80.4	0	0	-100.0	0	0
21.0	62.1	8.0	127.6	2.3	70.1	0	0	-100.0	0	0

[a] Risk-aversion coefficient from equation (1).
[b] Total returns (percent).

Table 10. Optimal Portfolios at Selected Risk-Aversion Levels (percent of total assets), 1953–2004

λ[a]	Expected Income[b]	Standard Deviation	Corporate Bonds	Corporate Stocks	Agricul. Assets	Gov't. Bonds	Money	Prime Rate	Small Stocks	Treasury Bills
					— One-Year Holding —					
1.0	8.7	16.0	0	0	26.1	0	0	-3.8	77.7	0
2.0	6.6	9.6	0	4.6	54.6	0	0	0	40.8	0
3.5	5.4	6.8	17.2	2.0	54.5	0	0	0	26.3	0
5.5	4.6	5.4	22.2	0.4	48.7	0	0	0	18.8	9.9
8.0	3.6	3.7	15.9	0	34.0	0	0	0	13.1	37.0
11.0	3.0	2.8	12.1	0	25.1	0	0	0	9.6	53.2
14.5	2.7	2.2	9.6	0	19.4	0	0	0	7.3	63.7
16.5	2.5	2.0	8.6	0	17.3	0	0	0	6.4	67.7
21.0	2.3	1.6	7.2	0	13.9	0	0	0	5.1	73.8
					— Five-Year Holding —					
1.0	83.2	41.0	0	0	0	0	0	-100.0	200.0	0
2.0	79.6	38.7	0	0	11.2	0	0	-100.0	188.8	0
3.5	54.5	22.8	0	0	26.2	0	0	-37.1	110.9	0
5.5	41.9	14.9	0	0.2	27.7	0	0	0	72.1	0
8.0	36.0	11.5	0	6.3	43.8	0	0	0	49.9	0
11.0	31.6	9.2	10.3	5.7	46.2	0	0	0	37.8	0
14.5	28.6	7.8	19.8	4.1	45.6	0	0	0	30.5	0
16.5	27.4	7.3	23.4	3.5	45.4	0	0	0	27.7	0
21.0	25.7	6.6	29.0	2.5	45.1	0	0	0	23.4	0
					— Ten-Year Holding —					
1.0	166.3	41.0	0	0	0	0	0	-100.0	200.0	0
2.0	166.3	41.0	0	0	0	0	0	-100.0	200.0	0
3.5	166.3	41.0	0	0	0	0	0	-100.0	200.0	0
5.5	128.7	29.0	0	0	32.9	0	0	-74.0	141.1	0
8.0	99.8	19.9	0	0	23.1	0	0	-20.1	97.0	0
11.0	83.8	14.9	0	0.2	27.7	0	0	0	72.1	0
14.5	74.6	12.2	0	4.9	40.2	0	0	0	54.9	0
16.5	71.2	11.3	0	6.7	44.9	0	0	0	48.4	0
21.0	64.4	9.5	7.8	6.3	46.7	0	0	0	39.2	0

[a] Risk-aversion coefficient from equation (1).
[b] Total returns (percent).

of agricultural assets ranged from 37% to 166% during the 1926–1952 time period, while the optimal percentage for the latter time period (1953–2004) ranged from 14% to 55% (Tables 9 and 10).

Other notable differences include percentages of corporate bonds, small company stocks, T-bills, and the amount of borrowing contained in the portfolios. Prior to the structural break, corporate bonds, small company stocks, T-bills, and borrowing entered into the efficient portfolios with respective ranges from 21%–132%, 0%–4%, 0%, and 0%–100%. These percentages are compared to the optimal portfolios after the structural break, which include corporate bonds (0%–22%), small company stocks (5%–78%), T-bills (0%–74%), and borrowing (0%–4%).

The portfolio results for the five- and ten-year planning horizons follow the same pattern as the one-year portfolio across the different levels of risk aversion (Tables 8–10). Similar to findings reported by Moss, Featherstone, and Baker (1987), the multiple-year holding periods consist of portfolios that are more leveraged and contain a higher percentage of agricultural assets at higher levels of risk aversion. Consistent with previous studies, our results suggest nonfarm investors could enhance their portfolios by investing in agricultural assets.

The results also reveal that the attractiveness of investments differs by the regime studied. Farm assets were more attractive during the 1920s through the early 1950s compared to the second half of the century. Consequently, perhaps data prior to the early 1950s should not be used when making asset allocation decisions because of a switch in the risk-return relationships.

It is useful to test the sensitivity of the results to the exclusion of leverage. The multivariate first-order autoregressive models were reestimated, after excluding the prime interest rate, to obtain the coefficients and residuals that were used to estimate the variance-covariance matrix. Then the optimal portfolios were again derived. As expected, the general results did not change, with a few minor exceptions for the 1926–2004 time period. When leverage was not allowed, government bonds did not enter into the optimal portfolio and corporate bonds represented a higher percentage in the optimal portfolio for the one-year holding period. For the five-year holding period, corporate stocks and government bonds did not enter into the portfolio, while corporate bonds entered at a higher percentage of total assets. In the ten-year holding period, neither corporate bonds nor stocks entered into the optimal portfolios.

Conclusions

Optimal investment allocations are typically derived under assumptions about investors' beliefs of the model's structural stability. However, economic and financial data are affected by changes in the data-generating process and are found to have effects on optimal investment allocations. This analysis contributes to the literature by testing for and examining the effects of structural breaks on investment allocations with agricultural assets as an investment option.

This study used a two-step maximum-likelihood approach of estimating the timing of the structural break and then estimating the optimal asset allocation conditional on that date. The framework indicated that the most likely break occurred during 1952. A mean-variance (EV) model was then employed to examine the optimal portfolios for single- and multiple-year holdings at varying risk-aversion levels.

Most investors would be unlikely to immediately invest a significant amount in agricultural assets because of potential liquidity concerns and lack of familiarity or experience with these assets. However, the results suggest that, relative to their risk, agricultural assets were underpriced and investors could gain by incorporating agricultural assets into their portfolio. For the entire time horizon (1926–2004), the percentage of agricultural assets contained in the portfolio ranged from 18% to 86% of total assets.

Our results suggest the optimal asset allocations, over a set of selected risk-aversion coefficients, before and after the break date are vastly different—which can be extremely misleading to an investor if structural change is not taken into account. For example, our analysis found agricultural assets entered into the optimal allocation for the period 1926–1952 at 37% to 166% of the total assets. However, after the break date (1953–2004), the percentage of agricultural assets in the portfolio was significantly lower (14% to 55% of total assets).

Because the percentage of agricultural assets differs in the optimal portfolios pre- and post-break, investors should perhaps be cautioned not to use the data prior to 1953 when making allocation decisions. These conclusions are robust when borrowing was excluded. Our results strongly demonstrate the importance of the time period selection when making decisions on allocating assets.

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Capital Structure, Firm Size, and Efficiency: The Case of Farm Petroleum and Animal Feed Co-operatives in Canada

Getu Hailu, Scott R. Jeffrey, and Ellen W. Goddard

Abstract

This paper examines the cost structure and cost efficiency for an unbalanced sample of 42 animal feed and 115 farm petroleum co-operatives in Canada over the period 1984–2001 using heterogeneous technology stochastic frontier models. The parameter estimates of the cost frontier and the resulting cost efficiency scores indicate there are statistically and economically significant cost inefficiencies. Further analysis revealed that financial structure and firm size have likely contributed to variations in cost efficiency. Obtaining sufficient equity capital is expected to improve co-operative efficiency.

Key words: agribusiness co-operatives, capital structure, cost efficiency

Co-operative business organizations play a major role in the agriculture and food industry of Canada, and have been a part of the Canadian agriculture sector for more than a century. Historically, the formation of agricultural co-operatives stemmed from economic concerns associated with market failures resulting from an unequal distribution of economic power and information. By acting together in co-operatives, farmers were able to gain much of the economic power associated with size.

Despite their historical contributions, over the past few years some co-operatives have seen a drop in their market shares. This period of decline in market share [Canadian Co-operative Secretariat (CCS), 2006] coincides with the time period during which many co-operatives have been characterized by capital constraints; that is, they have struggled with generating adequate capital (Hailu et al., 2005). The presence of capital constraints has led some co-operatives to reconsider their organizational structure. As determined in previous studies (e.g., Richards and Manfredo, 2003a, b; Chaddad and Cook, 2004), capital constraints have contributed to increased incidence of mergers, acquisitions, and demutualization by co-operative businesses.

Another factor contributing to weakened performance in agricultural co-operatives may be suboptimal debt financing decisions. Theoretically, leverage increases the pressure on managers to perform, because it reduces moral hazard behavior by reducing costs associated with "free cash flow."

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The free cash flow hypothesis (Jensen, 1986; Stulz, 1990) states that monitoring difficulty creates the potential for management to spend internally generated cash flow on projects that are beneficial for management (e.g., empire building, perquisite consumption, diversifying acquisition, cross-subsidizing poorly performing projects) but costly for shareholders. This hypothesis would suggest a potential for misuse of cash only when free cash flow is positive. The presence of debt may help mitigate the free cash flow problem, resulting in a positive relationship between preexisting debt and firm performance.

Conversely, higher leverage may increase agency costs of debt attributable to conflicting interests between co-operative shareholders/members and debtholders. This would result in a negative relationship between leverage and efficiency (Jensen and Meckling, 1976; Myers, 1977). As argued by Jensen and Meckling, a manager may be more likely to undertake projects that increase his/her personal benefits in spite of the increase in debtholders' exposure to risk than would occur if the manager financed the project with his/her own funds. Considerations such as the incentive to over-invest due to asset substitution (Jensen and Meckling, 1976), the incentive to under-invest due to limited liability (Myers, 1977), on-the-job excessive perquisite consumption due to partial ownership of the firm, asymmetric information (Barnea, Haugen, and Senbet, 1985), and/or inefficient liquidation policy (Harris and Raviv, 1990) may all contribute to higher financial leverage resulting in reduced efficiency.

The theoretical literature therefore provides alternative hypotheses regarding the relationship between financial leverage and firm performance. The empirical literature also provides mixed results, with some studies (e.g., Hubbard, 1998; Jensen, 1986; Stulz, 1990) supporting the free cash flow hypothesis while others (e.g., Kim and Maksimovic, 1990; Featherstone and Al-Kheraiji, 1995) find evidence of negative relationships between leverage and firm performance (i.e., agency costs).

The net effect of these factors (i.e., capital constraints and debt financing) may be that agribusiness co-operatives have a "suboptimal" capital structure leading to reduced cost efficiency. Cost efficiency refers to the degree to which actual cost is higher than the minimum or efficient cost of production. Capital constraints may prevent co-operatives from obtaining sufficient equity capital, leading to a higher leverage ratio. If there are significant agency costs of debt financing, this may result in higher costs.

The degree of efficiency attained by agribusiness co-operative organizations contributes directly to resource productivity and is a significant determinant of business performance. Inefficiency affects profits and growth through the negative effect of wasted resources, and affects earnings and cash flows due to suboptimal usage of the firm's resources (Greene and Segal, 2004).

Previous studies offer evidence suggesting that not all co-operative firms are fully efficient (e.g., Hailu et al., 2005; Singh, Coelli, and Fleming, 2001). Consequently, not all co-operatives succeed in minimizing the expenditures required to produce the outputs they chose to produce, which would enable them to achieve higher member patrons' income and future growth of the organization. It seems logical that increased efficiency is an important step in improving the competitiveness of co-operative organizations and in ensuring their continued viability as co-operatives.

Earlier studies have examined efficiency in agribusiness co-operatives (e.g., Caputo and Lynch, 1993; Ariyaratne et al., 1997, 2000; Evans and Guthrie, 2002). However, only a small number have investigated the impact of capital structure and agency costs, and their conclusions have been mixed. Although a few studies (e.g., Hailu, 2005; Hailu, Jeffrey, and Goddard, 2007) have examined the efficiency of Canadian agribusiness co-operatives, there have been no published efficiency studies focusing on Canadian farm supply co-operatives.

Knowledge regarding the current level of efficiency and opportunities to improve the degree of efficiency will be useful for co-operatives in helping them to maintain their viability. Improved viability of individual co-operatives would assist in ensuring a continued presence and significance of the co-operative business structure within the agribusiness sector into the future.

Accordingly, the objective of this study is to provide a better understanding of the inter-relationships among financial leverage, firm size, and cost efficiency in agribusiness co-operative organizations in Canada. Specifically, analysis is undertaken to address the following questions: "How efficient are Canadian farm petroleum and animal feed supply co-operatives?" and "What is the relationship between capital structure and the efficiency of farm petroleum and animal feed supply co-operatives in Canada?"

Conceptual Framework

In order to measure the efficiency of co-operative firms, a behavioral assumption of cost minimization is imposed—i.e., this study focuses on cost efficiency of supply co-operatives. Using the standard cost function, $C(y; \mathbf{w}) = \text{Min}\{\mathbf{x}\cdot\mathbf{w} \mid \mathbf{x} \in L(y)\}$, cost efficiency can be defined as:

$$CE(\mathbf{x}, y; \mathbf{w}) = \frac{C(y; \mathbf{w})}{\mathbf{x}\cdot\mathbf{w}},$$

where $C(y; \mathbf{w})$ is the efficient cost, $\mathbf{x}\cdot\mathbf{w}$ is the actual cost, y is output, $\mathbf{w}$ is a vector of prices of inputs, $\mathbf{x}$ is a vector of inputs, and $L(y)$ is the input requirement set formed by the isoquant of the desired y. The measure of cost efficiency is bounded between zero and unity, and achieves its upper bound if and only if a producer uses the efficient cost-minimizing input vector.

We propose a stochastic cost frontier for use in measuring the cost/economic efficiency of agribusiness supply co-operatives. Stochastic frontier analysis has been used extensively in agricultural economics research. Often, the focus of these studies is on an examination of firm-level factors that contribute to efficiency levels (e.g., Hadley, 2006; Osborne and Trueblood, 2006; Tauer and Mishra, 2006). However, cost frontiers have also been used for a variety of other purposes, including assessments of regulatory environments (e.g., Nadolnyak, Fletcher, and Hartarska, 2006), interregional competitiveness (e.g., Hailu, Jeffrey, and Unterschultz, 2005), and adoption of new technology (e.g., Alene, Hassan, and Demeke, 2005). An in-depth discussion of alternative frontier models is provided by Kumbhakar and Lovell (2000).

The general form of a stochastic frontier cost function for panel data may be expressed as (Kumbhakar and Lovell, 2000; Battese and Coelli, 1992):

$$(1) \qquad C_{ft} = C(\mathbf{w}_{ft}, y_{ft}; \boldsymbol{\beta}) + (v_{ft} + u_{ft}), \quad f = 1, \ldots, F;\ t = 1, \ldots, T,$$

where C_{ft} is the actual cost of the fth co-operative in the tth time period; $C(\mathbf{w}_{ft}, y_{ft}; \boldsymbol{\beta})$ denotes the theoretical cost function; $\mathbf{w}_{ft}$ is a $k\times 1$ vector of input prices for the fth co-operative in the tth time period; $\boldsymbol{\beta}$ is a vector of parameters to be estimated; v_{ft} is assumed to be an independently and identically distributed ($N(0, \sigma_v^2)$) stochastic error term with parameterized density $f_v(v \mid \cdot)$, and independent of u_{ft}; u_{ft} is assumed to be an independently and identically distributed nonnegative truncation of the normal distribution $|N(0, \sigma_u^2)|$, and thus accounts for cost inefficiency in production with a parameterized density of $f_u(u \mid \cdot)$.

The general procedure for estimating cost efficiency using equation (1) is to first estimate $\boldsymbol{\beta}$ and $\varepsilon_{ft} = v_{ft} + u_{ft}$, with a density of

$$f_\varepsilon(\varepsilon) = \int f_v(v) f_u(\varepsilon - v)\, dv,$$

and then to calculate cost efficiency for each observation in the sample as the conditional expectation $E(\exp(-u_{ft}) \mid \varepsilon_{ft})$. This provides an estimate of cost efficiency as the ratio of frontier (i.e., efficient) cost to actual cost. If distributional assumptions are imposed on the error terms, the approach involves determining the density function of ε_{ft}, $f(\varepsilon_{ft})$, and the joint density function $f(u_{ft}, \varepsilon_{ft})$, and then obtaining an expression for the conditional mean of $\exp(-u_{ft})$ based on the distribution $f_u(u_{ft} \mid \varepsilon_{ft})$.

Following the approach proposed by Jondrow et al. (1982) for disentangling the inefficiency effect and assuming a truncated-normal distribution, $u_{ft} \sim N[\mu, \sigma_u^2]$, for the inefficiency effect, the firm-specific inefficiency term is:

$$(2) \quad E[u_{ft} \mid \varepsilon_{ft}] = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\phi(\mu_f/\sigma\lambda - \varepsilon_{ft}\lambda/\sigma)}{1-\Phi(\mu_f/\sigma\lambda - \varepsilon_{ft}\lambda/\sigma)} - (\mu_f/\sigma\lambda - \varepsilon_{ft}\lambda/\sigma)\right],$$

where $\sigma = \sqrt{\sigma_v^2 + \sigma_u^2}$, and $\lambda = \sigma_u/\sigma_v$; μ_f is the mode/mean of the truncated normal distribution.[1] Once point estimates of μ_f are obtained based on equation (2), estimates of the cost efficiency (CE_{ft}) of each co-operative in an industry can be obtained from $CE_{ft} = \exp(-\hat{u}_{ft})$.

The next step in empirical efficiency analysis is the choice of functional form. For firm $f = 1, \ldots, F$ at time $t = 1, \ldots, T$, the stochastic translog cost function is employed here:

$$(3) \quad \ln(C_{ft}) = \beta_0 + \sum_i \beta_i \ln(w_{ift}) + 0.5 * \sum_i \sum_j \beta_{ij} \ln(w_{ift}) \ln(w_{jft}) + \sum_i \beta_{iy} \ln(w_{ift}) \ln(y_{ft}) + \beta_y \ln(y_{ft}) + 0.5\beta_{yy}(\ln(y_{ft}))^2 + (v_{ft} + u_{ft}),$$

where C_{ft} is the observed cost for the fth co-operative firm in the tth time period, w_{ift} is the price for the ith input of the fth co-operative firm in the tth time period (i.e., labor, capital, and materials), y_{ft} is output for the fth co-operative firm in the tth time period, the β's are parameters to be estimated, and v and u are as previously defined.

The translog form (Christensen, Jorgenson, and Lau, 1973; Diewert and Wales, 1987) is chosen because it does not impose any restrictive technological assumptions and allows the economies of scale, size, and density to vary with output. Flexible functional forms such as the translog provide a second-order approximation to the true underlying (but unknown) technology.

Regularity conditions require that the cost function in equation (3) be linearly homogeneous, nondecreasing, and concave in input prices. For the translog cost function to satisfy the linear homogeneity property of the cost functions, the following parameter restrictions must hold:

$$\sum_{i=1}^{n} \beta_i = 1, \quad \sum_{j=1}^{n} \beta_{ij} = 0, \quad \text{and} \sum_{i=1}^{n} \beta_{iy} = 0.$$

If the cost function is twice differentiable, a combination of Young's theorem and Shephard's lemma requires that the cross-effects in the set of input demand functions be symmetric. However, rather than applying Young's theorem to the actual cost function to obtain a set of restrictions, it can instead be applied to the translog approximation, so long as the translog approximation is twice continuously differentiable over the relevant range. This yields the following set of parameter restrictions: $\beta_{ij} = \beta_{ji}$.

In the estimation of cost functions, it is typically assumed that firms employ homogeneous technology. In practice, however, firms' technologies may be heterogeneous rather than homogeneous

[1] This formulation collapses to the efficiency estimate for the half-normal distribution if $\mu_f = 0$ (Aigner, Lovell, and Schmidt, 1977).

(Tsionas, 2002; Greene, 2002a, b, c; Orea and Kumbhakar, 2004; Huang, 2004; Battese, Rao, and O'Donnell, 2004). The underlying belief that all firms employ the same technology can be challenged, particularly for samples including a large and heterogeneous set of agribusiness co-operative firms. Agribusiness firms operate under different geographical and agro-ecological conditions and are managed by people with different managerial and technical skills. In addition, although co-operatives may have access to the same technology, they differ in the speed with which they adopt technological innovation. The implication is that firms within a sector use different technologies.

Models that examine the effect of policy measures (e.g., financial leverage policy, merger policy) at the co-operative level should account for such differences. If the assumption that firms' technologies are homogeneous is not valid, technological differences may be incorrectly labeled as (in)efficiency. Thus, it would be more appropriate to distinguish technological differences and technology-specific inefficiency rather than simply assume that firms share the same technology (Biorn, Lindquist, and Skjerpen, 2002). Random parameters models allow for the possibility of heterogeneous technologies, as the parameter estimates may vary by firm. As a result, the estimation of equation (3) is implemented using a random parameters stochastic frontier approach (Tsionas, 2002; Huang, 2004).

The general random parameters stochastic cost frontier formulation (Greene, 2002a) is as follows:

(4) $$C_{ft} = C(w_{ft}, y_{ft}; \beta_f) + (v_{ft} + u_{ft}),$$
$$f = 1, \ldots, F, \quad t = 1, \ldots, T,$$
$$\text{and } v_{ft} \sim N[0, \sigma_v^2],$$

where $u_{ft} = |u_{ft}|$, $u_{ft} \sim N[0, \sigma_u^2]$, and parameter heterogeneity is defined as:

(5) $$\beta_f = \beta + \xi_\beta \mathbf{d}_f + \Gamma_\beta \upsilon_{\beta_f},$$

where C_{ft}, w_{ft}, y_{ft}, and β_f are costs of production, input prices, output, and the parameter estimates, respectively, for the fth firm. The parameters β_f are distributed according to a K-variate normal distribution as: $\beta_f \sim N(\bar{\boldsymbol{\beta}}, \boldsymbol{\Omega})$, $f = 1, \ldots, F$, where $\bar{\boldsymbol{\beta}}$ is a $k \times 1$ vector of parameter means; $\boldsymbol{\Omega}$ is a $K \times K$ positive definite covariance matrix; and $\beta_f | \bar{\boldsymbol{\beta}}, \boldsymbol{\Omega}$ are assumed to be independent. The $\mathbf{d}_f$ vector includes variables related to the distribution of the random parameters and these are time-invariant; υ_{β_f} parameterize random variation which is assumed to have mean vector zero and known diagonal covariance matrix $\boldsymbol{\Sigma}_j$. $\boldsymbol{\beta}_f(\boldsymbol{\beta}, \boldsymbol{\xi}_{\boldsymbol{\beta}}, \boldsymbol{\Gamma}_{\boldsymbol{\beta}})$ is a matrix of parameters to be estimated. The parameter σ_v^2 is the variance of v_{ft}, and σ_u^2 is the variance of u_{ft}. When $\boldsymbol{\xi}_{\boldsymbol{\beta}}$ is a zero matrix, a simple random parameters model is obtained. A nonrandom slope parameters stochastic frontier model may be obtained by constraining corresponding rows in $\boldsymbol{\xi}_{\boldsymbol{\beta}}$ and $\boldsymbol{\Gamma}_{\boldsymbol{\beta}}$ to zero.

In order to estimate the parameters for equations (4) and (5), the unobserved random term υ_{jf} must be integrated out. Since the integrals will not exist in the closed form, but are instead in the form of expectations, they can be estimated by simulation.[2] The firm-specific inefficiencies are then based on firm-specific expected values of the random parameters.

Data Description

Data for Canadian animal feed supply and farm petroleum co-operatives are available from the annual surveys of agribusiness co-operatives conducted by the Canadian Co-operative Secretariat (CCS), Government of Canada.[3] This source is

[2] For more detail on this procedure, see Train (2002) and Greene (2002a).

[3] The CCS collects data on general company information (such as the number of employees and the number of members), income statement, and balance sheet information annually. Of the more than 1,300 total agriculture-based co-operatives, approximately 900 reported to the Canadian Co-operative Secretariat in 2001.

Table 1. Descriptive Statistics (Mean) for Canada's Agricultural Supply Co-operatives by Activity (1984–2001)

Description	Animal Feed		Farm Petroleum	
	Mean ($n*t$ = 619)	Standard Deviation	Mean ($n*t$ = 1,599)	Standard Deviation
Total Costs (mil. $)	11.275	17.326	6.358	45.465
Sales (mil. $)	12.428	18.922	7.120	50.697
Value Added (mil. $)	2.329	3.882	1.259	8.561
Return on Assets (ratio)	0.067	0.062	0.131	0.073
Debt-to-Assets (ratio)	0.457	0.212	0.109	0.127
Total Assets (mil. $)	5.014	8.221	2.897	17.327
Employees (number)	28	41	10	55
Members (number)	458	668	1,670	9,225

Notes: The term $n*t$ refers to the number of observations. Currency is in Canadian dollars.

used to obtain costs of production, wages and salaries, number of full-time and part-time employees, volume of sales, costs of goods sold, long-term debt, number of members, assets, liabilities, and other financial data for 157 reporting co-operatives. A summary of the data is provided in Table 1.

The data set for the unbalanced panel of 42 feed mill and 115 farm petroleum supply co-operatives over the period 1984–2001 is used in the efficiency analysis. In addition, data for the GDP deflator, fixed investment deflator, interest rate, raw material price indices, and farm input price indices are gathered from Statistics Canada (CANSIM) for the period 1984–2001.

- *Raw Material/Farm Input Prices* (M). Raw materials are treated as an aggregate input, excluding capital and labor, which are dealt with separately. Raw material price indices are collected from the Statistics Canada database, CANSIM. Cost of goods sold is used as a proxy for the value of raw materials.

- *Capital Price* (K). According to the opportunity cost principle, the unit cost of capital for a firm should be calculated as the rental value of the capital stock, as if the capital were being rented. The capital input group is an aggregate of land, buildings, machinery, and equipment. Using the GDP deflator and fixed capital price index, the relative price of one unit of capital with respect to production q is calculated for Canada for each year. In this study, per unit user cost of capital (r_k) is calculated as $r_k = (i - \pi + \delta) * q$, where i is the opportunity cost of capital, δ is the capital depreciation rate, q is the acquisition price of capital, and π is the rate of inflation in the economy.

- *Price of Labor* (L). The labor input consists of full-time and part-time labor. Both the number of employees and the total salary and wages are available from the sample data. The per hour wage rate is calculated assuming 40 working hours per week. There were several observations for which the calculated wage was extremely high (e.g., over $123 per hour) or low (e.g., $0.05 per hour). These "outliers" were assumed to have resulted from measurement error. In these instances, the calculated wages are truncated at $25 per hour from above and $10 per hour from below, with the upper and lower bounds being based on aggregate wage information from Statistics Canada.

- *Value Added* (y). The output variable represents value added (sales minus cost of goods sold). One of the challenges in estimating cost frontiers for supply co-operatives is that the direct measure of output (y) is difficult if not impossible to quantify accurately. Thus, value added is used as a proxy for y.

- *Total Cost* (C). The total cost represents the sum of expenses for materials, labor, and capital for the firm. Prior to estimation, value added and all price indices are normalized to one at the mean of the pooled sample.

- *Debt-to-Assets Ratio* (D_t/A_t). Debt-to-assets ratio is used as a measure of the degree of financial leverage. A greater proportion of debt relative to assets suggests that a co-operative took on more financial risk.

- *Lagged Debt-to-Assets Ratio* (D_{t-1}/A_{t-1}). Lagged capital structure is used as a proxy for agency cost based on the premise that the preexisting financial structure of the firm has a potential impact on the current production decisions and resulting cost efficiency. Assuming the existence of a significant conflict of interest between capital providers and managers that affects investment incentives, Kim and Maksimovic (1990) proposed a two-period (i.e., time t_0 and time t_1) agency model that relates the financial structure and the production decisions of a firm facing uncertainty concerning the level of demand for output. At time t_0 the firm chooses the financial structure by determining the level of capacity and debt. In addition, purchases of unobservable managerial efforts (or services) are made. At time t_1, taking the t_0 levels of capacity, debt, and effort as given, the firm decides on the level of variable inputs used in the production process. Since the input decision at time t_1 is conditioned on the choices made at time t_0, the capital structure decisions at time t_0 will affect the optimal input mix (and resulting cost efficiency) at time t_1. If agency costs of debt financing exist, a negative relationship between lagged capital structure and cost efficiency would be expected. Conversely, a positive relationship would suggest support for the free cash flow hypothesis discussed earlier.

- *Firm Size*. The data from CCS provide alternative measures of firm size: sales, number of members, number of employees, and assets. Correlations between these variables were calculated and sales were found to be highly correlated (i.e., coefficients of at least 0.90 or above) to other variables. Hence, the level of sales is used as a measure of firm size.

Model Results

The random parameters stochastic frontier models for the sample agribusiness co-operatives in this study are estimated using a maximum simulated likelihood routine in LIMDEP (NLOGIT 3.0.1). A comparison of the random parameters model (i.e., heterogeneous technology model) and the fixed parameters frontier model (i.e., homogeneous technology model) is conducted using the Bayesian information criterion (BIC), since the two models are nonnested. Based on the BIC values, the random parameters models best fit the sample data—i.e., the models incorporating heterogeneous technology.

The calculated BIC values for fixed parameter models are 838 and 1,899 for animal feed and farm petroleum, respectively, whereas the corresponding BIC values for the random parameters model are 64 and -339 for animal feed and farm petroleum. Thus, random parameters models are considered for further analysis of the cost frontier and cost efficiency measurements. The superiority of the heterogeneous technology model is consistent with previous findings of Tsionas (2002), Caudill (2003), and Orea and Kumbhakar (2004), among others.

Two separate random parameters cost frontiers are estimated: one each for

Table 2. Parameter Estimates for Random Parameters Stochastic Cost Frontier Model for Farm Supply: Animal Feed and Farm Petroleum Co-operatives in Canada

		Animal Feed		Farm Petroleum	
Variable	**Symbol**	**Parameter Estimate**	**Standard Deviation**	**Parameter Estimate**	**Standard Deviation**
Mean of Constant	β_0	14.329***	0.011	13.818***	0.012
Std. Deviation of Constant	$\Gamma_{\beta 0}$	0.798***	0.010	0.465***	0.005
Mean of *Raw*	β_1	0.663***	0.101	0.665***	0.042
Std. Deviation of *Raw*	$\Gamma_{\beta 1}$	0.252***	0.020	0.621***	0.006
Mean of *Labor*	β_2	0.097***	0.031	0.063***	0.018
Std. Deviation of *Labor*	$\Gamma_{\beta 2}$	0.012	0.016	0.030**	0.013
Mean of *Value Added*	β_y	0.685***	0.007	0.120***	0.008
Std. Deviation of *Value Added*	$\Gamma_{\beta y}$	0.043***	0.003	0.050***	0.010
Mean of *Raw*²	β_{11}	-0.217	0.393	-1.927***	0.184
Std. Deviation of *Raw*²	$\Gamma_{\beta 11}$	0.097	0.115	0.600***	0.101
Mean of *Raw* * *Labor*	β_{12}	-0.265**	0.124	-0.281***	0.105
Std. Deviation of *Raw* * *Labor*	$\Gamma_{\beta 12}$	0.623***	0.084	0.181***	0.068
Mean of *Labor*²	β_{22}	-0.087	0.094	-0.077	0.101
Std. Deviation of *Labor*²	$\Gamma_{\beta 22}$	0.222***	0.077	0.044	0.053
Mean of *Raw* * *Value*	β_{1y}	-0.099***	0.024	0.113***	0.021
Std. Deviation of *Raw* * *Value*	$\Gamma_{\beta 1y}$	0.439***	0.018	0.359***	0.016
Mean of *Labor* * *Value*	β_{2y}	0.032**	0.015	0.032**	0.015
Std. Deviation of *Labor* * *Value*	$\Gamma_{\beta 2y}$	0.028***	0.008	0.205***	0.011
Mean of *Value*²	β_{yy}	-0.091***	0.003	-0.125***	0.004
Std. Deviation of *Value*²	$\Gamma_{\beta yy}$	0.278**	0.002	0.078***	0.004
Time	β_t	0.023***	0.001	0.023***	0.001
Std. Deviation of *Inefficiency Effect*	σ_u	0.097		0.170	
Std. Deviation of *Random Effect*	σ_v	0.132		0.133	
	σ	0.163***	0.003	0.216***	0.001
	λ	0.734***	0.047	1.272***	0.029
Log-Likelihood Function		151.046		206.675	
Number of Firms		42		115	
$N * T$		619		1,599	

Note: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively.

animal feed and farm petroleum co-operatives.[4] The simulated maximum-likelihood estimates of the random parameters stochastic frontiers are provided in Table 2. The simulation is conducted using 150 draws of the Halton sequence. Most of the parameter estimates are statistically significant at the 5% significance level. With respect to regularity conditions of the cost function, the homogeneity and symmetry conditions are imposed prior to estimation on the cost function. The concavity and monotonicity conditions are checked after estimation at the mean value. The estimated share values for material, labor, and capital at

[4] Formal statistical tests were conducted to determine whether to estimate a single frontier for the sample co-operatives. Results from log-likelihood function value testing suggested there was a real difference in technologies between co-operatives in the two industries (i.e., animal feed and farm petroleum). Consequently, separate frontier functions were estimated for each type of co-operative.

the mean values are greater than zero. These findings suggest that, on average, the data satisfy the monotonicity condition in input prices for both models. For both frontiers, all eigenvalues for the matrix of elasticities of substitution are negative, indicating concavity conditions are satisfied at the mean value.

Measuring Efficiency

Using the parameter estimates from the cost frontiers and equation (2), cost efficiencies for individual firms are calculated. From the composed error variance parameter estimates in Table 2 (i.e., λ), it can be seen that there are statistically significant cost inefficiencies for sample co-operatives. The impact of inefficiency in explaining deviations from the frontier can be assessed by calculating the ratio of the variability in the inefficiency effect (i.e., σ_u^2) to total variability (i.e., $\sigma_u^2 + \sigma_v^2$). The results indicate that 35% and 62% of the deviations of the actual costs from the frontier costs are due to cost inefficiency (i.e., factors under the control of management) for co-operatives in the animal feed and petroleum industries, respectively.

Table 3 reports overall summary statistics of efficiency scores. For animal feed co-operatives efficiency scores range between 46.3% and 99.1% with an average of 85.4% suggesting that, on average, costs of production would have been reduced by about 15% had the co-operative been operating on the cost frontier. For farm petroleum co-operatives, the average level of cost efficiency is 80%, with values ranging from 1% to 99%. On average, costs of production for these co-operatives could have been reduced by approximately 20%.

In terms of inter-firm efficiency variation within the sector, there is less variation among the firms operating in the animal feed industry (with a coefficient of variation of 14%) as compared to the firms operating in the farm petroleum industry (with a coefficient of variation of 23%).

Table 3. Distribution of Cost Efficiency for Random Parameters Model for Animal Feed and Farm Petroleum Co-operatives

	Efficiency Scores		
Co-operative	**Range**	**Mean**	**Std. Dev.**
Animal Feed	0.46–0.99	0.85	0.12
Farm Petroleum	0.01–0.99	0.80	0.19

The differences in average efficiency and inter-firm efficiency variation are likely an indication of a greater degree of homogeneity for animal feed co-operatives, rather than suggesting that these co-operatives are more efficient than the petroleum co-operatives. Overall, relative to their cost frontier, sample co-operatives operate inefficiently with observed cost roughly 15–22% above the minimum.

Inefficiency Effects

What causes an organization to spend more than the minimum for a specific level of outputs? What factors are associated with a higher or a lower cost efficiency? A tobit regression analysis is undertaken to examine the determinants of cost efficiency for animal feed and farm petroleum co-operatives, where cost efficiency is the dependent variable. Parameter estimates from this regression measure the magnitude of the impact on cost efficiency for changes in the explanatory variables.

The following two simultaneous equation tobit model is specified for each industry:

(6)
$$CE_{ft}^{*} = FL_{ft}'\gamma + x_{1ft}'\delta + e_{1ft},$$
$$FL_{ft}' = x_{2ft}'\Pi + e_{2ft},$$
with
$$\begin{bmatrix} e_{1ft} \\ e_{2ft} \end{bmatrix} \sim N\left(0, \begin{pmatrix} \sigma_1^2 & \sigma_{12}' \\ \sigma_{21} & \sigma_{22} \end{pmatrix}\right)$$
for $f = 1, \ldots, N$,

where $\mathbf{x}_{ft}' = (x_{1ft}', x_{2ft}')$ is a vector of observations on the maintained weakly exogenous variables; FL_{ft}' is the degree of financial leverage (i.e., potentially endogenous variable); γ, δ, Π, and σ's are parameters to be estimated; and CE^{*}_{ft} is latent efficiency (i.e., censored endogenous variable) where we only observe:

$$CF_{ft} = \begin{cases} CE^{*}_{ft} & \text{if } CE^{*}_{ft} > 0, \\ 0 & \text{otherwise.} \end{cases}$$

The use of a tobit efficiency equation requires the assumption that the degree of financial leverage is exogenous. This assumption is tested using exogeneity tests (Smith and Blundell, 1986). The potential endogeneity hypothesis is based on the argument that creditors might lend mainly to the most efficient co-operatives (i.e., based on credit evaluation).

Exogoneity of financial leverage is rejected for the three models individually. Thus, the simultaneous equation is estimated to correct for endogeneity of financial leverage. Because of a potential nonlinear relationship, the Taylor's series expansion is used to introduce quadratic and interaction terms of the exogenous variables. The effects of financial leverage and firm size on efficiency are calculated as $\partial E[CF_{ft}]/\partial FL_{ft}$ and $\partial E[CF_{ft}]/\partial SIZE_{ft}$, respectively.

Table 4 provides parameter estimates for the simultaneous equation tobit model. On average, the debt-to-assets ratio has a negative impact on the cost efficiency for animal feed (i.e., $\partial E[CF_{ft}]/\partial FL_{ft} = -0.066 < 0$) and farm petroleum (i.e., $\partial E[CF_{ft}]/\partial FL_{ft} = -0.522 < 0$) co-operatives. Higher financial leverage has contributed to lower cost efficiency for supply co-operatives. The benefit of financial leverage should be weighed against the potential costs of financial distress/risk (i.e., bankruptcy costs, costs of conflicts of interest, and other indirect costs[5]) arising from the use of excessive debt.

In order to investigate the impact of agency costs of debt (i.e., costs arising from conflicts of interest), the preexisting proportion of debt (Kim and Maksimovic, 1990; Featherstone and Al-Kheraiji, 1995; Hailu et al., 2005) is included in the inefficiency effects model. Results suggest that the coefficients for preexisting proportion of debt, as measured by the lagged debt-to-assets ratio, are negative for co-operatives operating in the animal feed industry. This finding supports the agency costs hypothesis (i.e., $\partial E[CF_{ft}]/\partial LDEBT_{ft} = -0.06 < 0$): increased leverage results in reduced efficiency. In the case of farm petroleum co-operatives, the results support the free cash flow hypothesis (i.e., $\partial E[CF_{ft}]/\partial LDEBT_{ft} = 0.147 > 0$): increased leverage contributes to improved efficiency.

An explanation of the contrasting results for animal feed versus farm petroleum co-operatives, with respect to evidence of agency costs, is not obvious. The animal feed co-operatives in the sample have, on average, significantly larger asset bases than do the petroleum co-operatives (Table 1). It may be the case, therefore, that co-operatives in this sector are more susceptible to capital constraints, leading to agency costs of debt.

The results for the petroleum co-operatives suggest that in the presence of free cash flow, the distribution of retained earnings may create conflicts of interest between managers and members of these co-operatives, which may in turn negatively affect cost efficiency. Thus, these firms may benefit from increased financial leverage (i.e., increased use of debt) in this situation (Jensen, 1986). However, the optimal level of financial leverage cannot be determined based on this study. The optimal capital structure depends on the tradeoffs between the direct tax benefits and the indirect costs or default costs related to leverage.

Firm size is incorporated into the cost efficiency equation in order to control for the impact of size and member diversity on cost efficiency of individual co-operatives. Results suggested that, on average, size has a positive impact on the cost efficiency of animal feed co-operatives

[5] Indirect costs may relate to the increase in financing costs as investor/creditors worry about the future payments, and the increase in operating costs as suppliers or members become reluctant to make long-term commitments with the firm.

Table 4. Simultaneous Equations Tobit Model Parameter Estimates for Farm Supply: Animal Feed and Farm Petroleum Co-operatives in Canada, 1984–2001

	Animal Feed		Farm Petroleum	
Variable	**Parameter Estimate**	**Standard Deviation**	**Parameter Estimate**	**Standard Deviation**
Cost Efficiency Tobit Regression:				
Constant	0.906***	0.015	0.692***	0.019
Sales	-0.170***	0.007	-0.064***	0.009
*Sales * Sales*	0.014***	0.001	5.5E-04**	2.7E-04
Debt-to-Assets	0.157***	0.059	0.864***	0.179
Debt-to-Assets^2	0.095	0.116	0.877***	0.085
*Sales * Debt-to-Assets*	0.086***	0.011	0.029***	0.011
Lagged Debt-to-Assets	-0.075***	0.026	0.187*	0.100
Leverage Regression Equation:				
Constant	0.402***	0.026	0.280***	0.010
Return on Assets	-0.838***	0.102	-0.479***	0.028
Sales	0.112***	0.018	0.008	0.005
*Sales * Sales*	-0.019***	0.006	-6.9E-05	1.6E-04
Trend	0.006***	0.001	-0.005***	0.000
Fixed Assets to Total Assets	-0.116**	0.058	-0.112***	0.014
Variance Parameters:				
σ_{12}/σ_{22}	-0.190***	0.040	-1.915***	0.149
$\sigma[e_1{:}\ e_2]$	0.048***	0.001	0.136***	0.003
σ_1^2	0.003		0.069	
σ_2^2	0.030		0.014	
ρ	-0.571		-0.854	
Log-Likelihood Function	2,653.404		5,816.630	
$\partial E[CF_{ft}]/\partial FL_{ft}$	-0.066		-0.522	
$\partial E[CF_{ft}]/\partial SIZE_{ft}$	0.120		-0.035	
$\partial E[CF_{ft}]/\partial LDEBT_{ft}$	-0.060		0.147	

Note: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively.

(i.e., $\partial E[CF_{ft}]/\partial SIZE_{ft} = 0.120 > 0$), and a negative impact on the cost efficiency of farm petroleum co-operatives (i.e., $\partial E[CF_{ft}]/\partial SIZE_{ft} = -0.035 < 0$).

Mosheim (2005) found that the number of members had a negative impact on scale efficiency and positive effects on allocative, technical, and cost efficiencies. Albaek and Schultz (1997) showed that for co-operatives with many members (small or large), efficiency will not prevail if the investment cost is equally shared among members with different levels of patronage. Furthermore, Grossman and Hart (1988) argue that efficiency may require votes to be distributed according to "the size of patronage." Growth in the number of members, and ultimately in firm size, may conflict with the governance and stability of the co-operative organization. According to Zueli (1999, p. 1236), "a larger, more diverse membership often leads to a governance problem. Are all groups represented ...?"

Concluding Remarks

In this paper we explore the cost structure and cost efficiency for an unbalanced sample of 42 animal feed and 115 farm petroleum co-operatives in Canada over the period 1984–2001 using random parameters stochastic frontier models. The parameter estimates of the cost frontiers and the resulting cost efficiency scores indicate there are statistically and economically significant cost inefficiencies in each category—i.e., an average cost inefficiency of 15% for animal feed co-operatives, and 20% for farm petroleum co-operatives.

This evidence suggests there may be significant potential for reducing the cost of providing services to members without cutback in services provided. For example, the cost of providing services for farm petroleum co-operatives would have been decreased by approximately 20%, on average, had the co-operatives operated at their respective frontiers, while providing the same level of service. Decision makers may focus on using resources of their co-operatives (i.e., labor, capital, and material) more efficiently.

Given the empirical evidence reported in this analysis for the sample firms, the following conclusions are noted:

- The approach used to estimate cost efficiency is important.
- The estimated cost inefficiencies are statistically significant for both animal feed and farm petroleum co-operatives.
- Contemporaneous financial leverage has a negative impact on efficiency of both animal feed and farm petroleum co-operatives.
- Preexisting financial leverage, as a proxy for agency costs of debt, has a negative impact on animal feed co-operatives and a positive impact on farm petroleum co-operatives.
- There is a negative relationship between firm size and cost inefficiency for farm petroleum co-operatives, and a positive relationship for animal feed co-operatives.

What is causing efficiency to differ by size group? Although further empirical research is warranted to fully answer this question, an intuitive explanation for the relationship between firm size and efficiency within a specific industry is based on economies of scale and organizational theory. The basic implication of technological and organizational theories emphasizing transaction and agency costs of firm size is that within a specific industry (common production technology) and within a common institutional environment, firm size and efficiency may be linked through a tradeoff of economies of scale and transactions costs and agency costs.

Agency and transaction cost theories may help to explain why different sized firms coexist. If economies of scale dominated, it could be expected that all co-operative activities would be conducted by larger organizations. In situations where the benefits of small size are not sufficient to outweigh the benefits of economies of scale, large firms will predominate. In other cases, where agency and transaction costs are great or where economies of scale are not significant, a smaller size may be optimal. In the case of farm petroleum co-operatives, transaction and agency costs of size may more than offset the benefits from economies of scale.

Next, what is causing cost efficiency to decline with preexisting financial leverage for the sample co-operatives in the animal feed industries? Further empirical research may illuminate the latent causes of the inverse relationship. However, one possible explanation for the inverse relationship between cost efficiency and preexisting financial leverage may be that adhering to co-operative principles has made it difficult for co-operatives to lower financing costs by raising relatively cheaper funds from public investors/stock market.

This conclusion has important implications for co-operative incentive structure reform. Obtaining sufficient equity capital is expected to improve co-operative efficiency. A potential area of future research would be to evaluate the efficiency of New Generation Co-operatives (NGCs). NGCs differ from traditional co-operatives in that the initial equity investment made by members is more significant, resulting in a larger initial pool of capital for the co-operative. Examining the cost efficiency of NGCs would provide a means to test whether greater equity does lead to greater efficiency for co-operatives.

While the empirical results are specific to supply co-operatives in Canada and in the specific sectors examined here, there is no reason to think they would not generalize to supply co-operatives dealing in different products or located in other countries. In particular, it would seem that financial structure has significant implications for efficiency in supply co-operatives.

Interestingly, these results are consistent with similar analysis conducted for Canadian agribusiness marketing co-operatives (Hailu, Jeffrey, and Goddard, 2007) where increased leverage was shown to have a detrimental effect on efficiency. Further research in this area is likely warranted in order to provide further documentation regarding the links between financial structure and leverage in agribusiness co-operatives.

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Marginal Impact of Sales Consultant Visits and Financing Opportunities on Adoption of Variable-Rate Fertilizer Application

William E. Nganje, Mary S. Friedrichsen, Cole R. Gustafson, and Gregory McKee

Abstract

Precision agriculture has been practiced since the early 1990s, but the adoption rate of this technology has been slower than experts had predicted. This study explores the role of public- and private-sector financial assistance in the adoption of variable-rate fertilizer application. Public- and private-sector financial assistance are modeled to show the marginal impacts of changes in the traditional flow of government assistance, sales consultant visits, and financial risk. Results indicate that deviation from traditional "one-stop shopping" has a negative and significant impact on the adoption of alternative fertilizer application technology. However, sales consultant visits, in conjunction with conservation and environmental quality incentive programs and the availability of financing opportunities, significantly favor the adoption of variable-rate fertilizer application. Changes in business risk produced opposite movements in financial risk to facilitate increased adoption of variable-rate fertilizer application technologies.

Key words: financing opportunities, multinomial logit model, risk balancing, variable-rate fertilizer application

Precision agriculture is a technology system being implemented by many farmers into their own production practices to help control sensitive environmental problems, reduce the quantity and cost of fertilizer application, and increase profitability. Precision agriculture involves a range of management practices that attempt to utilize site-specific information at the field level, such as soil characteristics and weather conditions, in order to adjust farm inputs and ultimately achieve optimal output (National Research Council, 1997).

An example of precision agriculture technology is variable-rate fertilizer application. Although this technology has been practiced since the early 1990s, the adoption rate has been slower than experts had predicted. A recent survey of farmers in the Midwest [American Farmland Trust (AFT), 2005] revealed approximately two-thirds of farmers in this region do not use variable-rate application technology. Some studies have identified the high cost of adoption, uncertainty about profitability, and potential financial risks (Cook, Adams, and Bramley, 2001; Griffin and Lowenberg-DeBoer, 2005; AFT, 2005; Knight and Malcolm, 2007) as major reasons for the slower than predicted adoption rate.

Direct public assistance, through government support and university extension programs, has historically served as a tool to lessen the financial burden or cost for farmers, mitigate risks, and provide incentives to adopt environmentally friendly technologies. For example, a major reason farmers may

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adopt precision agriculture techniques (such as variable-rate fertilizer application) is that by doing so they may become eligible to receive benefits from government programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Security Program (CSP).

The Farm Service Agency (FSA) and other USDA service branch offices have traditionally been thought of as a "one-stop shop" for enrolling in such government programs and becoming eligible for the benefits associated with these programs. This one-stop-shop process is changing for agri-environmental government programs due to the limited number of Natural Resources Conservation Service (NRCS) personnel, high research and development investment from private industry, and the projected wide and prompt acceptance of these programs. The change in the delivery method for public financial assistance programs may be one possible explanation for the slow adoption of variable-rate fertilizer application technology—a concern we address in this research.

The NRCS is creating another avenue for the implementation of these programs. Sales consultants from private industry are partnering with NRCS and have been retained to help determine farmers' local resource needs and to assist in implementing plans for improved management.

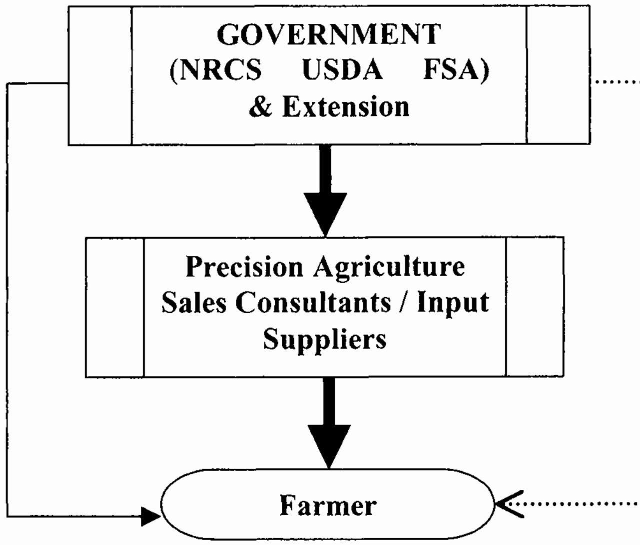
AFT (2007) reported that government assistance tools to protect farmers against financial loss from variable-rate application can be offered by private companies, crop sales consultants, and state agencies (if available). Certified private industry personnel act on behalf of the NRCS in creating "best management plans" which will enable farmers to receive financial assistance from the government under these programs. Figure 1 illustrates the traditional one-stop approach and the current flow of information/assistance between farmers and public agencies.

Farmers are accustomed to receiving education/assistance through public research. In the case of precision agriculture, however, they are being educated, for the most part, through visits from sales consultants from private companies. Most research on precision agriculture has been privately funded, as universities have received little funding for such research (Lowenberg-DeBoer, 1998). Private companies have therefore undertaken to educate farmers about the use and availability of alternative technologies. However, because these companies are interested in making profits, farmers may be skeptical about the claimed benefits of the various services or goods being offered, thereby slowing the adoption of these technologies.

Based on results of a recent survey (AFT, 2005), farmers indicated they were least willing to work with private for-profit companies to obtain public financial assistance for variable-rate fertilizer application technology. Consequently, farmers may not accurately perceive or be sufficiently convinced of the economic and environmental benefits of these technologies, or the role of public financial assistance (as outlined by Gardner and Rausser, 2001) in educating them about variable-rate application and lessening their financial burden.

The focus of this paper is the role and marginal impact of the change in the delivery method for public financial assistance on the adoption of precision agriculture technology and increased financing opportunities to offset changes in business risk. A multinomial logit model is used to analyze specifically how the newly created partnership between NRCS and the private sector of precision agricultural professionals has impacted the adoption of variable-rate fertilizer application. We also test the hypothesis that positive net worth/increased financial stability will enhance the adoption of precision agriculture.

This study provides three major contributions to the existing literature on technology adoption:



Notes: Solid arrows and represent new information flow with 2002 Farm Bill agri-environmental programs; dotted arrow ....> represents traditional information flow with previous government programs.

Figure 1. Flow of Information in Government Programs

- First, we evaluate the marginal impact of information flow/public assistance delivery changes arising from the implementation of a public/private partnership program on the adoption of variable-rate application technology.

- Second, we assess the role of increased financing opportunities in balancing business risk from the high cost of variable-rate technology equipment and potential yield variability. The risk-balancing hypothesis suggests that changes in business risk might produce opposite movements in financial risks (Collins, 1985; Barry and Robison, 1987; Escalante and Barry, 2001).

- Third, this analysis extends the traditional set of farmer behavior and farm characteristics to include existing and potential policy variables, such as the number of sales visits from private consultants in conjunction with government incentive programs intended to enhance the precision technology adoption process.

Adoption of Precision Agriculture

Although variable-rate fertilizer technology has been available since the early 1990s and was one of the first frontier technologies of precision agriculture, the industry is not yet in its mature stage. Lowenberg-DeBoer (1997) contends that precision agriculture will not fit the classic S-curve model of technology adoption for reasons beyond the farmer's control. The classic S-curve model for the growth and demand for a new product is split into three major segments: introduction and early adoption, acceptance and growth of the market, and maturity with market saturation. He explained that slow adoption might have been caused by unexpected costs such as incompatibility between software, monitors, and equipment, repair delays, and expensive equipment provided by sales consultants from private industry. Moreover, Griffin and Lowenberg-DeBoer (2005) suggest that land, labor, fertilizer, energy costs, and uncertainty in profitability in certain regions, as well as farm and farmer characteristics, could affect adoption rates.

Other studies on the adoption of agricultural technology have focused more on farm and farmer attributes (Adesina and Chianu, 2002; Gardner and Rausser, 2001; Caviglia and Kahn, 2001; Khanna, 2001; Khanna, Epouhe, and Hornbaker, 1999; Daberkow and McBride, 2003; Roberts et al., 2004; Sevier and Lee, 2005).

Gardner and Rausser (2001) summarized the variables found to impact a farmer's decision to adopt new technology. These variables can be grouped into three categories: (*a*) farm characteristics such as farm size, geographical or location factors, type of crop rotation practiced, and soil types; (*b*) farmer characteristic variables such as the level of education, risk attitudes and experience, and financial stability and net worth; and (*c*) exogenous policy variables such as the level of public, unbiased research on the new technology, financial leverage, information flow, private-sector intervention, and government incentive programs.

McBride and Daberkow (2003) studied the relationship between the sources of information available to farmers and the adoption of precision agriculture, and found that information from crop consultants and input suppliers has had the greatest impact on the adoption of precision agriculture. However, their emphasis was on marketing information and not specifically on public financial assistance information.

Building on these earlier works, our research seeks to effectively combine and consider all of the variables identified above, and focuses on four major categories of variables affecting the adoption of variable-rate fertilizer application technology: (*a*) the method of information flow/financial assistance, (*b*) farm characteristics, (*c*) farmer characteristics, and (*d*) exogenous policy variables.

Theoretical Model and Data

In theory, farmers will adopt production methods they perceive as being the most profitable and convenient, given the conditions of their farming operations. It is assumed that choosing a particular method of fertilizer application technology indicates a farmer perceives that system as being relatively more profitable than the alternatives.

Profits received by the jth farmer from producing crops using the ith production technology are represented by the variable B_{ij} (Schuck, Nganje, and Yantio, 2002). These profits are a function of farm attributes including total acres, soil type, various crops the farmer has in his or her rotation, land location, and the value of crop revenue; farmer characteristics, including level of education, net worth, and years in farming; and exogenous variables, including the possibility to increase leverage or obtain loans, private-sector sales visits, and government incentive programs.

Profit is included in this model since it captures all the items one could not represent in a demand model. Therefore, the expected utility of potential profits, $U(B_{ij}(X))$, is a function of farm attributes, farmer attributes, and other exogenous factors, X. For a grower to shift from one method of fertilizer application to another, the expected utility from potential profits (Π) under the ith production method must be at least as large as those under the base method that the farmer is already implementing. Thus,

$$(1) \quad \Delta U(\Pi) = U(\Pi_{ij}) - U(\Pi_{0j}) > 0,$$

where $i = 0$ denotes the base fertilizer application technology. In this study, the base method of fertilizer application is a uniform (flat-rate) application.

One of the principal problems when dealing with calculations of the costs and benefits associated with precision agriculture technology is that the costs of implementing the technology are mostly private and borne by the farmer, while many of the benefits, including the environmental benefits, are public. As a result, farmers may not adopt new precision agriculture variable-rate fertilizer technology because they reap only a portion of the benefits. For it to be worthwhile to adopt the technology, the farmer must be convinced that the private benefits exceed the private costs.

In the present framework, the goal is to assess whether or not sales consultant visits and government financial assistance programs will help convince farmers it is in their best interest to adopt variable-rate technology, and consequently help speed the adoption of better environmental agriculture practices.

To accomplish this objective, changes in government programs and sales consultant visits must increase the difference in expected utility from perceived profits between uniform fertilizer application and the alternative methods of production. Hence, government assistance programs and sales visits must make farmers more aware of the profit potential in using variable-rate fertilizer application technology methods rather than the uniform application. However, individual farmers respond to education and government programs differently, and financial stability as well as social and personal characteristics may limit an individual farmer's adoption of new precision agriculture technology. Accordingly, this issue must be addressed through the development of an empirical model.

The model adopted in this study follows Caviglia and Kahn (2001) and Adesina and Chianu (2000) in assuming a random utility framework for the farmer's utility-maximization problem. Given this, each farmer maximizes expected utility by opting for the production practice with the highest perceived profits, expressed as:

$$(2)\quad U\big(\Pi_{ij}(X)\big) = f_{ij}X + \varepsilon_{ij},$$

where $f_{ij}X$ is a deterministic function of farm attributes and ε_{ij} is a random variable representing unobserved attributes. It is not necessary to estimate each farmer's utility or profit function. The probability of adopting a particular production method, expressed as a function of farm, farmer, and exogenous attributes, can instead be estimated using a discrete choice model. This can be accomplished by assuming $f_{ij}X$ takes the form $\boldsymbol{\beta}_i\mathbf{X}_j$, where $\boldsymbol{\beta}_i$ is a vector of parameters associated with the production method, and $\mathbf{X}_j$ is a vector of observed farm, farmer, and policy attributes.

Translating the difference in expected utility into a workable limited discrete choice model requires assuming a distribution for the difference between ε_{ij}'s. Assuming the ε_{ij}'s are random independent variables following a Weibull distribution, the distribution of the difference between them is logistic (Domencich and McFadden, 1975). Since farmers are assumed to choose among three alternative fertilizer application technologies, the model outlined in equation (2) reduces to a multinomial logit model where the probability of implementing a particular fertilizer technology is a function of both farm and farmer attributes, public financing assistance, and visits by precision agriculture sales personnel.

Farmers can choose among many various forms of variable-rate application technology. Here we focus on the four main options in applying fertilizer: uniform, trial, grid, and management zone application. The choice of uniform fertilizer application (base technology) is made outside the framework of the model, so the probability of selecting the base technology is indeterminate. This indeterminate problem can be overcome by normalizing β_0 (i.e., the coefficients for uniform or flat-rate application) to zero (Amemiya and Nold, 1975). Once this is done, the probability of the ith production method by the jth farmer is specified as:

$$(3)\quad \Pr_{ij} = \frac{e^{\mathbf{X}_j\beta_i}}{\sum_i e^{\mathbf{X}_j\beta_i}}.$$

Since profit is the main factor in the farmer's production system, a farmer might choose the cheapest fertilizer application method, which could be uniform rate. But due to the risk of over- or under-fertilization and the social costs and benefits, the uniform rate application might not be optimal for the field's production potential. We must analyze the marginal impacts of core determinants affecting the adoption of alternative fertilizer application technologies. The set of parameters $\boldsymbol{\beta}$ reflects the changes in $\mathbf{X}$ on the probability. The change in the probability of adoption of variable-rate precision agriculture technology with each change in the independent variables is given by:

$$(4)\quad \frac{\partial P_j}{\partial X_{km}} = (1 - P_m)P_j\beta_k .$$

Study Area, Survey Procedure, and Data

Because the data needed for this analysis were not readily available, a survey instrument was developed and mailed to farmers in the study areas of Minnesota, North Dakota, and northern South Dakota. Three pre-tests of the survey were completed between May 31 and August 1, 2004, and survey data were collected from September 1 through November 30, 2004. The pre-testing was used to evaluate sensitive questions and improve the clarity of the survey instrument.

Farmers who were contacted were selected randomly from a precision agriculture consulting business list. Farmers on the list were identified by the precision agriculture consulting firm as current or potential customers of precision agriculture equipment. This sample consists of a representation of farmers who have adopted variable-rate technology and farmers who have not adopted variable-rate technology. The survey was created with three main sections: (*a*) farmer characteristics, (*b*) farm and production data, and (*c*) exogenous policy variables and information on usage of precision agriculture technology.

The first section of the survey (farmer characteristics) requested the following information: age of the farmer, number of years the farmer has been employed in farming, land location, total acres farmed, and percentage of owned versus rented land in the farming operation. The farmer's level of education was requested using the following five-point scale: 1 = less than high school, 2 = high school diploma, 3 = some college, 4 = college degree, and 5 = post-doctoral degree. Information was also collected as to which soil texture types (clay, loam, and sandy soils) comprise the farmer's fields and the type of crop rotation the farmer utilizes (soybean, wheat, sugar beets, and corn; soybean, wheat, and corn; soybean and corn; and soybean, other oilseeds, and barley). These were modeled as dummy variables.

The second section of the survey (farm and production data) collected crop-specific, labor, and financial information. Crop-specific information included acreage, average yield, and average price the farmer receives for the crop. Labor information, including number of employees, was split into five seasonal time frames to determine if labor is a limiting factor during different time periods throughout the growing season.

Financial information included total value of farm assets, net worth, and whether the farmer has obtained debt to finance variable-rate technology adoption. The value of farm assets was broken into six ranges following the USDA's guidelines: 1 = <\$200,000, 2 = \$200,000–\$499,999, 3 = \$500,000–\$999,999, 4 = \$1,000,000–\$1,999,999, 5 = \$2,000,000–\$4,999,999, and 6 = >\$5,000,000. Estimated net worth of the farm operation was defined as assets minus liabilities, with six ranges supplied for farmers: 1 = <\$100,000, 2 = \$100,000–\$249,999, 3 = \$250,000–\$499,999, 4 = \$500,000–\$999,999, 5 = \$1,000,000–\$2,499,999, and 6 = >\$2,500,000.

Within the precision agriculture technology section of the survey, information was collected on how the farmer currently uses precision agriculture technology, if at all, whether the farmer plans to implement precision agriculture technology in the future, and when the farmer was first exposed to the technology. For the existing and potential policy variables, the survey asked if the farmer is enrolled in environmental-based government programs, if the farmer plans on enrolling in new agri-environmental government assistance programs, and how often the farmer receives sales visits from private precision agriculture companies.

When analyzing the data, it was clear that some farmers utilize more than one fertilizer application technology on their farms. The survey farmers were divided into one of four technology groups, including three specific application options and a trial state. The three specific application options are (*a*) uniform, (*b*) grid soil variable rate, and (*c*) management zone (satellite-based) variable rate. If a farmer devoted greater than 60% of the farm's acres to one of these specific application options, then he/she was assigned accordingly to that group. If the farmer was still experimenting with alternative application methods, then the farmer was assigned to the trial stage.

A comparison is needed to ensure that the separation into the four groups is distinct. A nonparametric Mann-Whitney test (also known as the Mann-Whitney *U*-test when *U* is calculated) is used for this purpose. This test is employed instead of the parametric *t*-test because of deviations from normality and the differences in the sample sizes of participants in each group. With the calculated symmetric *z*-values (e.g., for trial and management zone of 5.21) and a *p*-value of 0.0001, we conclude that producers in the categorization are significantly distinct.

Financing opportunities might prove to be barriers to the adoption of precision agriculture technology. However, potential cost limitations can be offset by the possibility of increasing the financial leverage ratio to purchase new technology. The financial leverage ratio measures the firm's total obligations to creditors (lenders) as a percentage of the equity capital provided by the owners and the degree of indebtedness or ability to meet other financial obligations (Barry et al., 2000). Lenders prefer borrowers to have at least as much invested in their own business as lenders do. Sellers of new equipment will generally arrange financing for the purchase of this equipment. The marginal impact of increased net worth or financial stability for alternative fertilizer application technology is also analyzed in this study.

Detailed descriptive statistics of the data are presented in Table 1. The survey was mailed to farmers on the precision agriculture consulting business list. A total of 268 usable questionnaires were returned, representing a response rate of approximately 36%. The individuals on the business list can be considered a representative pool of farmers in the Upper Midwest, as the farm characteristics of the survey respondents are similar to those documented by Swenson (2002) for North Dakota farms.

Estimation Procedure and Results

N-Logit econometric software is used to estimate the multinomial logit model. The model does not include the intercept term since the robustness of the model—defined by the R^2, the percentage of correct predictions, and the number of significant variables in the model—does not change after running an iteration without the intercept. The fertilizer application variable is the dependent variable in the multinomial logit model, and sales visits, total acres, years in farming, education level, net worth, soil type, crop rotation, land location, enrollment in government agri-environmental programs, the interaction term between financing opportunities and sales visits, and the interaction term between enrollment in government programs and sales visits are independent variables.

Table 1. Descriptive Statistics of Data

Variable	Mean	Minimum	Maximum	Std. Dev.
Age (years)	45	23	67	9.12
Years in Farming	23	4	47	9.39
Acres Farmed	2,599	54	15,000	2,538.44
Acres Owned	973	0	6,000	1,255.56
Acres Rented	1,628	0	9,000	1,665.49
Acres of: ▸ Flat	1,780	54	15,000	2,519.08
▸ Grid	503	40	2,200	636.97
▸ Management Zone	897	40	6,500	1,380.94
No. of Sales Visits per Year	3.17	0	45	0.94
Obtained Financing	1.08			
Net Worth	\$500,000–\$999,999			
% Farmers Invested in Precision Ag.	68%			
No. of Observations	268			

Source: Survey data

Education level and net worth are measured on scales defined earlier, ranging from 1–5 or 1–6 according to the survey; soil type and crop rotation are measured using dummy variables; land location is measured as distance from private-sector sales representatives; the financing opportunity variable (leverage) equals 2 if the farmer obtained financing for precision agriculture technology, and 1 if not; and the government assistance program variable is a dummy variable equal to 1 if the farmer is enrolled to receive assistance, and 0 if not.

Soil type is divided into three main categories: clay (clay and silty clay), loam (loam and silty loam), and sand; and crop rotation is divided into four categories: soybean, wheat, sugar beet, and corn (crop rotation 1); soybean, wheat, and corn (crop rotation 2); soybean and corn (crop rotation 3); and other oilseeds and barley (crop rotation 4). Dummy variables were created for soil types and crop rotation.

The interaction variables are created using the financing opportunity variable and the government programs variable and multiplying them with the sales visits from private precision agriculture sales personnel. Other variables collected from the survey are not included in the model due to multicollinearity problems.

The percentage of correct predictions is calculated as the total number of correct predictions divided by the number of observations. This model results in 75.76% correct predictions. The χ^2 value is 81.46 with a significant probability (χ^2 > value) of 0.0000. To further test the robustness of the model, choice-based sampling is applied. With choice-based sampling, the coefficients are not affected, but the estimation errors are minimized. Mathematically, the estimated variance with choice-based sampling is given as follows (Greene, 2003):

$$(5)\quad \text{Est. Var}[\hat{\beta}] = \left[\sum_{i=1}^{n}\left(\frac{\partial^2 \log(F_i)}{\partial\hat{\beta}\partial\hat{\beta}'}\right)\right]^{-1} \times \left[\sum_{i=1}^{n}\left(\frac{\partial \log(F_i)}{\partial\hat{\beta}}\right)\left(\frac{\partial \log(F_i)}{\partial\hat{\beta}'}\right)\right] \times \left[\sum_{i=1}^{n}\left(\frac{\partial^2 \log(F_i)}{\partial\hat{\beta}\partial\hat{\beta}'}\right)\right]^{-1}.$$

The full-information maximum-likelihood procedure in N-logit is used to estimate the multinomial logit model parameters and to ensure that estimated parameters are efficient and unbiased.

The results for the multinomial logit model are reported in Table 2. For farmers who are in the trial stage, total acres, soil type, years the farmer has farmed, formal education of the farmer, and financing opportunities/sales visits significantly impact the probability of adoption at the 1% level. Sales visits and crop rotation 3 are significant at the 5% level.

Within the group of farmers who have implemented grid variable-rate technology in their programs, soil type, years in farming, formal education of the farmer, sales visits, financing opportunities/sales visits, and government programs/sales visits are significant are the 1% level. Crop rotation 1 is significant at the 5% level, and the farmer's net worth is significant at the 10% level. For the farmers who have adopted management zone technology, soil type loam, years in farming, and sales visits are significant at the 1% level. Total acres, soil type clay, crop rotation 1, education, net worth, and the financing opportunities/sales visits and government programs/sales visits interaction variables are significant at the 5% level.

Total acres farmed and the level of formal education have positive impacts on the adoption of variable-rate technology. The number of years the farmer has farmed, on the other hand, negatively impacts the decision to adopt variable-rate technology. This result may imply a perception of increased experience and knowledge of the farm and a reluctance to adopt a new technology that farmers may think they do not need. This finding is consistent with those reported by Khanna, Epouhe, and Hornbaker (1999) and AFT (2005). In the AFT survey, some farmers indicated they would not adopt variable-rate fertilizer application because their current system is not "broken." Land location, or the further away the farmer is from private-sector sales representatives, does not have a significant impact on the adoption of management zone technology.

In the subsections below, we focus on the impact of three important variables that can be used by policy makers to foster the adoption of variable-rate fertilizer application technology: sales consultant visits, government programs, and financing opportunities.

Sales Consultant Visits and the Adoption of Variable-Rate Fertilizer Application

Table 2 shows how important sales visits by precision agriculture consultants are in determining the farmer's choice of fertilizer application technology. Sales visits are found to have a negative impact on the farmer's decision to adopt or increase variable-rate application technology. These results are similar for the grid and management zone technologies, indicating robustness. It is possible that farmers view sales consultants as profit seekers. The results suggest possible dislike of and retaliation against the public/private delivery of program information. In the survey group, 41% of farmers reported they have received a sales visit from a precision agriculture consultant, with an average of three visits per year.

Government Programs and the Adoption of Variable-Rate Fertilizer Application

Enrollment in government programs is not found to have a significant impact on the adoption of variable-rate technology (table 2). Eighty-one percent of farmers responded that they were interested in an agri-environmental program. However, the insignificant effect of government programs could be explained by the farmers' answers to a question about why they were not enrolled in EQIP. When creating this question, it was assumed farmers would answer, for example, that they were not eligible for the government program, or that there was limited funding for their county. Instead, some farmers noted they were not aware of the program. About 11% replied with "do not like government intervention," because of "too much red tape," and "not enough dollar incentive."

Table 2. Results of Multinomial Logit Model

Variable	Coefficient	Standard Error	P[|Z| > z]
	— TRIAL TECHNOLOGY —		
Farm Characteristics:			
Total Acres	0.0019	0.0007	0.0050
Soil Type Clay	-19.7479	7.5947	0.0093
Soil Type Loam	-13.0976	4.3567	0.0026
Crop Rotation 1	3.4938	2.3781	0.1418
Crop Rotation 2	1.5260	1.1040	0.1669
Crop Rotation 3	10.4104	4.7951	0.0299
Land Location	-0.0745	0.0545	0.1714
Farmer Characteristics:			
Years in Farming	-0.3511	0.1160	0.0025
Education	4.5438	1.6643	0.0063
Net Worth	0.5569	0.4515	0.2174
Exogenous Policy Variables:			
Sales Visits	-2.8197	1.1736	0.0163
Government Programs	0.6813	1.2688	0.5913
Financing Opportunities/Sales Visits[a]	3.8544	1.3285	0.0037
Government Programs/Sales Visits[a]	0.9226	0.5821	0.1130
	— GRID TECHNOLOGY —		
Farm Characteristics:			
Total Acres	0.0011	0.0007	0.1176
Soil Type Clay	-50.8748	7.8037	0.0000
Soil Type Loam	-14.1341	4.5436	0.0019
Crop Rotation 1	-6.8566	3.2632	0.0356
Crop Rotation 2	-0.9697	1.8401	0.5983
Crop Rotation 3	7.1975	4.8680	0.1393
Land Location	-0.0383	0.0671	0.5681
Farmer Characteristics:			
Years in Farming	-0.4038	0.1300	0.0019
Education	5.0387	1.7985	0.0051
Net Worth	0.9731	0.5659	0.0855
Exogenous Policy Variables:			
Sales Visits	-2.7840	0.9013	0.0020
Government Programs	0.9231	1.6241	0.5698
Financing Opportunities/Sales Visits[a]	4.7336	1.4818	0.0014
Government Programs/Sales Visits[a]	1.0469	0.4025	0.0093
	— MANAGEMENT ZONE TECHNOLOGY —		
Farm Characteristics:			
Total Acres	0.0015	0.0007	0.0248
Soil Type Clay	-18.7915	8.3105	0.0237
Soil Type Loam	-12.3261	4.3579	0.0047
Crop Rotation 1	-5.6386	2.2653	0.0128
Crop Rotation 2	1.6129	1.2478	0.1962
Crop Rotation 3	6.9742	4.4534	0.1173
Land Location	-0.0171	0.0579	0.7674

(continued . . .)

Table 2. Continued

Variable	Coefficient	Standard Error	P[|Z| > z]
— MANAGEMENT ZONE TECHNOLOGY (cont'd.) —			
Farmer Characteristics:			
Years in Farming	-0.3806	0.1446	0.0085
Education	4.2105	1.7036	0.0135
Net Worth	1.7824	0.8461	0.0342
Exogenous Policy Variables:			
Sales Visits	-1.8368	0.6945	0.0082
Government Programs	0.5669	1.6240	0.7270
Financing Opportunities/Sales Visits [a]	3.9545	1.6767	0.0184
Government Programs/Sales Visits [a]	0.6118	0.2643	0.0206

[a] Interaction terms

Although 11% of the farmers stated they do not like government intervention, most farmers do not directly perceive the benefits of variable-rate technology because of the failure of information transmission due to deviations from the traditional "one-stop-shopping" adoption process and financial limitations.

Financing Opportunities and the Adoption of Variable-Rate Fertilizer Application

Net worth positively and significantly impacts the probability of adopting grid and management zone technologies. The positive impact of net worth is an indication that the profitability of using grid or management zone technologies within the operation is important to increase farmers' adoption rate, and federal programs that mitigate yield variability and profitability should be encouraged. The probability of adopting variable-rate technology increases when farmers perceive the technology will improve their net worth. Recently, studies have documented that variable-rate technology can be profitable for farmers in certain circumstances (Koch et al., 2004; Wang et al., 2003).

One would expect increased leverage to negatively impact variable-rate technology, especially because of the significant implementation costs and risks involved. The farmer is paying the sales consultant for knowledge services and equipment. However, the results indicate that the more farmers have the opportunity to increase leverage and finance precision agriculture, the higher the probability of adopting grid and management zone technology. This is an indication that upward adjustments in debt levels may be warranted to invest in variable-rate technology if levels of business risk decrease or as farmers perceive increased profits and understanding of environmental benefits and public support programs like those implemented by AFT.

This is an interesting policy variable, suggesting tailored credit programs for variable-rate fertilizer technology will greatly enhance the adoption of precision agricultural technology. These results also reveal that the risk-balancing hypothesis does provide some explanation for the adoption of variable-rate fertilizer application technology.

Marginal Impacts

The marginal impacts of variables averaged over individual farmers on the probability of adopting variable-rate fertilizer technology will enable us to further understand potential strategies for policy design. Determining the marginal impact of private-sector sales visits on the adoption of precision agriculture is

Table 3. Summary of Marginal Impacts

Variable	Technology Group Uniform (0)	Trial (1)	Grid (2)	Mgmt. Zone (3)
Total Acres	0.0001	0.0001	0.0000	0.0000
Land Location	0.0017	0.0073	0.0011	0.0044
Crop Rotation 1	0.1802	0.2668	0.2290	0.2181
Crop Rotation 2	0.0472	0.1451	0.1908	0.0929
Crop Rotation 3	0.3210	0.5915	0.1235	0.1471
Soil Type Clay	0.8663	1.1569	0.0000	0.5304
Soil Type Loam	0.4832	0.2282	0.1591	0.0960
Years in Farming	0.0139	0.0012	0.0050	0.0077
Education	0.1672	0.0772	0.0674	0.0227
Net Worth	0.0422	0.1014	0.0062	0.1373
Sales Visits	0.0899	0.1221	0.0332	0.0654
Government Programs	0.0068	0.0911	0.0515	0.1358
Financing Opportunities/Sales Visits [a]	0.1500	0.0143	0.0841	0.0516
Government Programs/Sales Visits [a]	0.0302	0.0323	0.0213	0.0234

[a] Interaction terms

especially important if the precision agriculture training continues to be through the private sector and the government does not implement more public research and traditional extension education strategies.

Soil type, crop rotation, education, financing opportunities/sales visits, sales visits, and net worth have the greatest marginal impacts on the adoption of uniform technology (Table 3). As indicated earlier by Bronson (2003), soil type variability and sampling strategy play an important role in the adoption of variable-rate fertilizer application technology.

Figure 2 shows that the probability of farmers practicing uniform fertilizer technology decreases as sales visits by precision agriculture private-industry consultants increase. As financing opportunities increase in conjunction with sales visits, then the probability of adopting uniform technology decreases and the probability of adopting grid or management zone technology increases. Farmers are willing to increase financial leverage to adopt better technology once they understand the benefits of these technologies.

Net worth has a negative marginal impact on the adoption of uniform or trial technology and a positive impact on the adoption of grid and management zone technology. As shown by Figure 3, the probability that the farmer will practice uniform fertilizer application methods decreases as net worth increases.

The most important variables for farmers with grid and management zone technology are still government assistance programs, sales visits, financing opportunities/sales visits (for grid only), and the interaction between government programs and sales visits. For farmers who employ management zone technology, an increase in sales visits in conjunction with financing opportunities led to an increase in the adoption of more precision agriculture technology. The results suggest that intensifying outreach efforts with experimental trial plots for management zone technology should lead to a higher adoption rate.

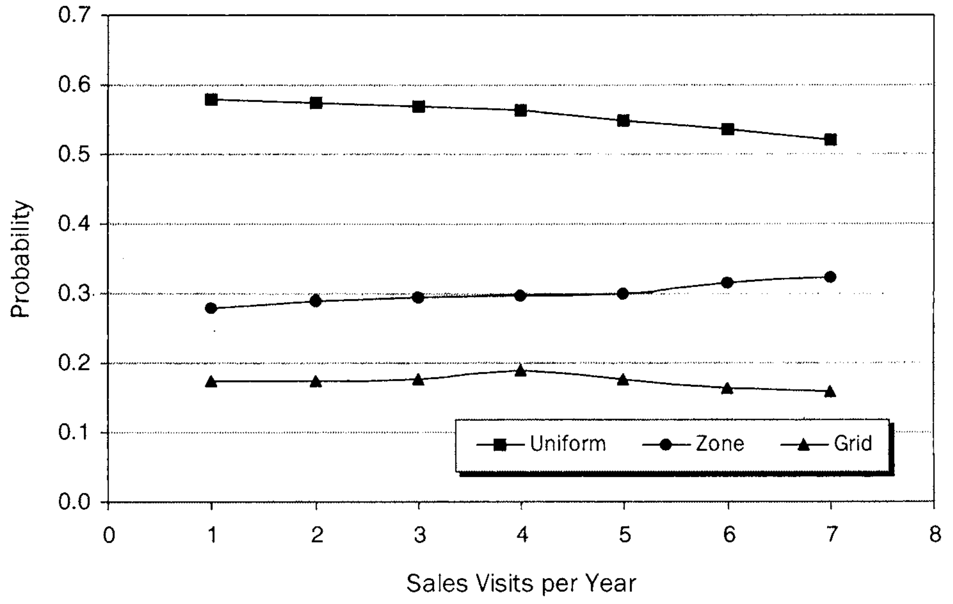


Figure 2. Probability of Adoption as a Function of Sales Visits per Year

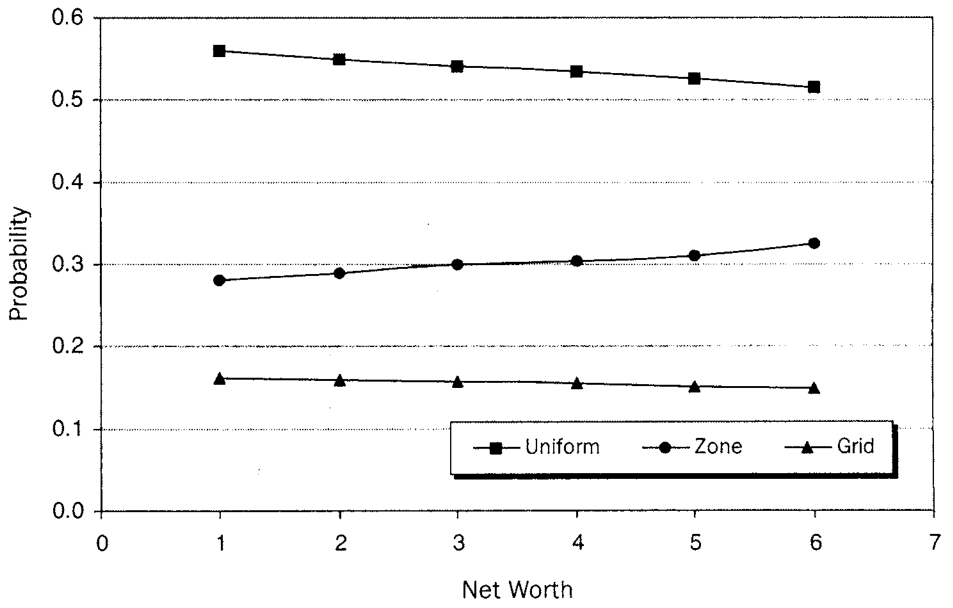


Figure 3. Probability of Adoption as a Function of Net Worth

Government assistance programs had a significant and negative marginal impact on the adoption of grid and management zone technologies. One can conclude that an increase in sales visits by precision agriculture industry personnel, especially when the visit is for the farmer's government program incentives, will negatively impact the adoption of precision agriculture technology. Further, enrolling in agri-environmental government programs will not significantly affect the likelihood of farmers adopting variable-rate precision agriculture technology. These results may be due to deviations from the one-stop adoption process.

Financing opportunities/sales visits had a positive and significant marginal impact on farmers adopting variable-rate technology in their operation. Farmers are willing to increase financial leverage to adopt better technology once they understand the benefits of these technologies. Also, the positive and significant marginal impact of the government assistance programs/sales visits variable suggests that using both variables in concert to better educate farmers about variable-rate fertilizer application technology, especially for the grid technology, will increase the probability of adoption.

Conclusions and Policy Recommendations

Producer and public interest in environmental issues will remain heightened due to concern for safe drinking water and other environmental and natural resource issues. In recent years, public attention has turned toward nutrients in the Mississippi River Basin and the growing hypoxia problem in the Gulf of Mexico, which may be related to nitrate loading. The government has identified precision agriculture technology as a way to help manage natural resource concerns. An important question is whether farmers perceive environmentally friendly government programs and private-sector intervention as an effective strategy to help control natural resource concerns such as nonpoint pollution while still keeping their farms profitable in the long run.

This study uses survey data collected from farmers in North Dakota, Minnesota, and South Dakota to analyze the impact of agri-environmental government programs on the adoption of variable-rate fertilizer technology. Results indicate that transitioning from entirely public information delivery to public/private partnerships will have a negative impact on the adoption of precision agriculture. However, if farmers are familiar with the benefits and linkages between government assistance programs and sales visits by private precision agriculture sales personnel and if financing opportunities are available, they are more willing to balance business and financial risks to increase adoption of variable-rate fertilizer application technology.

The cost required for precision agriculture technologies is decreasing as the technologies improve. Moreover, with the government seeking to promote agri-environmental programs, the time appears to be right for the adoption of precision agriculture. However, caution must be exercised to tailor adoption efforts on core policy variables with greater and significant marginal impacts. Varying programs could be developed which focus on each specific technology group. These programs should consider the impact of deviation from the one-stop shopping experienced with visits from private precision agriculture sales personnel, and such programs should also be structured to address financing opportunities with affordable rates.

Prior models assessing technology adoption have focused mainly on farm and farmer characteristics. Here we have extended this framework to include exogenous policy variables and risk-balancing mechanisms, showing that these variables might have greater marginal impacts and policy implications. Extending this study to other regions and states in the country would be a worthwhile future research effort.

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Cooperative Risk Management, Rationale, and Effectiveness: The Case of Dairy Cooperatives

Mark R. Manfredo and Timothy J. Richards

Abstract

Numerical simulation of several typical risk management strategies using pro forma financial statements from representative U.S. dairy cooperatives shows that combinations of forwards, swaps, and cash marketing strategies for output (cheese), along with various forward contracts offered to cooperative members to manage the variability of milk revenues, have the potential to improve cooperative-, and ultimately member-level risk-return performance. Because most cooperatives have limited access to equity capital, effective use of available risk management tools can increase cooperative value by increasing debt capacity, avoiding bankruptcy costs, and preventing the distortion of capital budgeting decisions. Moreover, the offering of risk management tools to individual members as a service may prove valuable in the retention of these members in the cooperative.

Key words: cooperative, expected utility, futures, options, risk management, value-at-risk

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Like all agricultural businesses, agricultural cooperatives operate in an environment that is inherently risky. Because most cooperatives tend to be relatively narrowly focused on a particular commodity, region, or level of the marketing channel, they tend to have a comparatively high degree of business risk. Furthermore, limited access to public equity markets and the requirement to return earnings to members often indicate that cooperatives are highly leveraged, and hence are also exposed to considerable financial risk. It is perhaps surprising then that many cooperative managers tend to accommodate, rather than actively manage, the various sources of risk they face as a business entity (CoBank staff, 2001).

A lack of active risk management among investor-oriented firms is less surprising in light of the accumulated theoretical knowledge on this issue. Investor-oriented firms often justify their lack of risk management on the basis of the "risk management irrelevance proposition" (RMIP). The RMIP suggests that firms cannot increase their value by engaging in active risk management (e.g., hedging) since it costs the same for the firm to bear risks as it would to pay the capital markets to do so (Stulz, 2003). If shareholders can manage risks by hedging on their own account, then attempts by management to achieve the same result are largely redundant (Modigliani and Miller, 1958; Miller and Modigliani, 1961). Consequently, risk management activities theoretically cannot be undertaken to improve shareholder wealth.

Despite the elegance and logical consistency of this proposition, it is based on a highly restrictive set of assumptions. If these assumptions are relaxed, firms can indeed add value in a number of different ways by actively managing risk (Cummins, Phillips, and Smith, 1998; Smith and Stulz, 1985; Smithson, 1998). Namely, active risk management can reduce nontradable risks, mitigate financial distress and costs of bankruptcy, reduce taxes, and increase debt capacity, thereby helping to avoid costly equity financing.

While there is some empirical evidence showing these sources of value can arise among investor-oriented firms, for cooperatives they remain largely theoretical in nature (Mian, 1998). However, given the unique member-owner structure of cooperatives, the case for active risk management may be even more compelling for cooperatives than for investor-owned firms. This is particularly true given that many cooperatives compete directly with investor-owned firms for patronage of member-producers (Zeuli and Betancor, 2005).

Thus, if active risk management by the cooperative is viewed as a service to members as part of their cooperative membership, it may help in attracting and retaining membership—especially if competing investor-owned firms are engaged in active risk management, and/or provide producers with a way to manage their own risks (e.g., through the offering of forward price arrangements, etc.). Accordingly, cooperatives that accommodate rather than manage risks may inadvertently place themselves at a strategic disadvantage in attracting and retaining members in the presence of competing investor-owned firms.

Given the above discussion, the overall objective of this research is to determine how alternative risk management strategies employed by cooperatives may impact the risk-return profile of the cooperative as a business entity, and ultimately that of cooperative members. Specifically, we examine this issue by simulating the impact of several risk management strategies using real-world financial data from a set of representative U.S. dairy cooperatives.

Focusing on dairy cooperatives provides a unique case since dairy cooperatives are inherently multi-product in nature, allowing for the examination of strategies designed to manage the risks of both risky inputs and output. Dairy cooperatives also allow for the simulation of risk management strategies that are already available (e.g., exchange-traded futures and options) as well as innovative over-the-counter transactions such as revenue swaps, forward contracts, and other contractual arrangements. Furthermore, dairy cooperatives remain an important marketing institution in the United States, compete directly with investor-owned milk processing firms for milk throughput, and some dairy cooperatives already actively provide risk management services to their members.[1]

Since dairy cooperatives are multi-product firms where both input price and output price variability impact the distribution of net income at the cooperative level, we focus on how alternative risk management strategies influence the distribution of cooperative net income, profits that may ultimately be returned to members in the form of patronage refunds or equity redemptions. Active risk management by the cooperative is also likely to impact commodity prices received by members, and subsequently member revenues and profits. This is particularly true if the cooperative provides risk management services to members, such as forward contracting arrangements, which are likely to impact the distribution of net income at both the cooperative and member levels, depending on how the forward contracts are structured. Hence, we also consider how these risk management strategies impact net income at the member level.

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[1] For example, see the forward contract arrangements provided by Alto Dairy at http://www.altodairy.com/producers/contracts/choices/.

Because each risk management strategy is likely to have a different effect on cooperative and member net income, the relative effectiveness of each strategy is compared to all others using a variety of performance measures. Assuming cooperative managers and members are motivated by risk and return objectives, but are sensitive to the size and probability of downside risks, the measures used in this analysis consider: (*a*) expected utility of profit, (*b*) mean-variance utility, and (*c*) downside risk (e.g., value-at-risk and semivariance). Ranking each of the strategies examined with these different metrics allows for the identification of a preferred strategy, or set of preferred strategies.

An understanding of how alternative risk management strategies may impact the financial performance of cooperatives and their members is important, especially as cooperative managers compete for patronage directly with investor-owned firms. If active market risk management strategies are shown to improve the risk-return profile of cooperatives and their members, this finding may provide an additional impetus for cooperatives to embrace risk management principles, particularly given the complex risks faced by cooperative members in the current agricultural economy. Indeed, active risk management at the cooperative level, as well as the provision of risk management services to members, may prove to be an important value-added component of cooperative membership.

In the section below, we describe how active risk management can aid cooperatives and their members, especially in light of the RMIP, and also outline the empirical model used to evaluate alternative risk management strategies. The next section presents the data used to calibrate the empirical model, followed by a section devoted to the findings from the simulation. The final section provides a discussion of implications for the use of cooperative risk management strategies and offers concluding remarks.

Sources of Cooperative Risk and Risk Management Objectives

Cooperatives are exposed to several risks both similar and unique to investor-owned firms. Risk-averse agricultural producers often join cooperatives because of the risk reduction received from assurance of a market, diversification from risk-sharing and pooling, benefits from vertical integration, and other benefits usually associated with agricultural cooperatives (Cropp et al., 1998). While cooperative membership provides these elements of risk reduction, cooperatives as business entities are still subject to considerable business and financial risks.

Moreover, cooperatives tend to operate in low-margin, commodity-based products, and so do not benefit from the stability of retail or often even processing margins. Also, because most small cooperatives likely operate in narrowly defined geographic, product, or enterprise markets, they are often less diversified than similar investor-oriented businesses.

The requirement to return earnings to members and the reluctance to issue public equity capital suggest cooperatives tend to be overly reliant on debt financing. Consequently, volatility in cooperative financial performance simultaneously affects both the cooperative business entity and member-producers alike. In many ways, the importance of sound risk management may be even greater for cooperatives relative to investor-oriented firms given cooperatives often have limited access to capital and given the unique attributes of their business and financial risk profiles.

If cooperative managers can effectively mitigate risk, there is likely a large, latent demand for risk management products. There is reason to believe this is indeed the case as the risk management irrelevance principle is less likely to hold among cooperatives than investor-oriented firms. For instance, within cooperatives, some risks are "nontradable" due to asymmetrical information between owners and management. Because cooperatives do not issue publicly traded stock, member-owners do not have the same ability as common shareholders to diversify their risk exposure.

While some individual cooperative members working in certain industries have access to exchange-traded futures and options to manage price risks, they may find these instruments difficult to use given cash flow constraints (e.g., posting of margin), execution costs (e.g., commissions), an overall lack of knowledge in hedging and risk management, and a general reluctance to hedge despite educational efforts (Shapiro and Brorsen, 1988). Thus, actively managing risks and/or providing risk management services to member-producers, who might otherwise be reluctant to manage risks on their own, can be viewed as a valuable service to members.

Cooperatives that actively engage in risk management activities may also be able to mitigate the costs of financial distress, namely legal fees, regulatory costs, and indirect costs such as deterioration with customers and members (Smith and Stultz, 1985; Cummins, Phillips, and Smith, 1998). This is especially true based on the high debt-to-asset ratios typically exhibited by cooperatives. Along these lines, reducing the volatility of income, and subsequently the volatility of interest-coverage, cooperatives can increase their debt capacity.

On a related point, by reducing risks, cooperatives need to hold less capital in reserve, and are therefore able to allocate scarce capital more efficiently. This improved financial flexibility allows the cooperative to fund positive net present value projects without new equity capital—a significant benefit given the inherent capital constraints faced by cooperatives (Richards and Manfredo, 2003).

While the above arguments make a solid case for the usefulness of active risk management practices by cooperatives, co-op managers still may be reluctant to engage in these activities, choosing instead to accommodate rather than manage risks. Additionally, consistent with the RMIP, some cooperative members may be in a position to better manage their own risk exposures than to have this activity undertaken by the cooperative. This is particularly true for members who produce commodities where government and private insurance markets exist, as well as for large, well-capitalized producers who may be more willing and able to effectively use exchange-traded futures and options markets. Cooperative managers may regard risk management as a task more appropriate for individual members rather than the cooperative as a whole.

Agricultural cooperatives are also subject to Financial Accounting Standards Board (FASB) rule 133, which specifies that certain derivative products must be "marked to market" or valued on company financial statements at the current market value. Because this rule can create a significant tax liability, along with resources and costs associated with compliance, many risk management products are typically written into supply contracts rather than entered into explicitly. Moreover, given the fairly recent negative experience of the "hedge-to-arrive" crises, many smaller cooperatives are now often reluctant to use the strategies available to them (Baumel and Lasley, 1997).

Regardless, given the unique risks faced by agricultural cooperatives, a case can be made for the merits of active risk management. In particular, cooperative managers can provide a service to member-owners by engaging in active risk management on their behalf. This service may be particularly salient as many cooperatives compete for patronage directly with investor-owned firms. Nevertheless, especially in light of some arguments against active risk management, it remains to be seen if this is the case in practice. A thorough understanding of the risk and return characteristics of alternative risk management strategies, at both the cooperative and member levels, can help in aiding cooperative managers and members alike in assessing the value of active risk management.

Empirical Model of Cooperative Risk Management

Dairy cooperatives provide a good opportunity to study the impact of risk management on financial performance because they tend to face both input and output price risk, their production technology is relatively standard and well understood, and cooperative managers have, for the first time in decades, a variety of market-traded risk management products available.

In order to create a model that is tractable, yet still captures the fundamental sources of market risk faced by dairy cooperatives and their members, we maintain the cooperative principle of "user ownership" and "user benefits" such that the financial success of the cooperative and owner are inextricably linked. Therefore, we define the dairy cooperative members' profit as arising from two sources: (*a*) from selling milk to the cooperative, and (*b*) patronage refunds and equity redemptions resulting from cooperative membership (Zeuli and Betancor, 2005). Thus, cooperative member profits can be defined as:

(1) $\pi_{Mem} = \pi_{Milk} + \pi_{Coop} - c_p$,

where π_{Milk} is the member revenue (unhedged) received from marketing milk through the cooperative, px, where p is the milk price received from the cooperative and x is a fixed quantity of milk marketed through the cooperative; c_p reflects costs of milk production at the producer-member level.

Similarly, in considering cooperative profit, π_{Coop}, we assume cooperatives purchase a fixed amount of fluid milk (x) from members, process it, and sell an amount of cheese ($q = \alpha x$) into cash cheese markets, where α is the production technology describing the conversion of milk into cheese.[2] The unhedged cooperative profit (π_{Coop}) can be expressed as:

(2) $\pi_{Coop} = p_c q - p_m x - c(q) - c$,

where $p_c q$ is the profit from cash market sales of cheese at price p_c, $p_m x$ reflects the cost of milk to the cooperative at fluid milk price p_m and fixed milk throughput x, $c(q)$ is variable processing costs, and c is fixed costs incurred by the cooperative. Cooperative profits as defined in (2) can be returned to cooperative members in the form of patronage refunds or equity redemptions. Therefore, π_{Coop} can be thought of as patronage refunds and the present value of any equity redemptions.[3]

Based on this model, cooperative managers have choices available to them in terms of risk management. They may (*a*) sell cheese and acquire milk from cooperative members at current market prices, (*b*) treat the cooperative similarly to an investor-owned firm and manage input and output price risks at the cooperative level, and/or (*c*) provide risk management tools, such as forward contracts, to cooperative members as a service, potentially augmenting the distribution of both cooperative profits and members' milk revenue simultaneously. In consideration of the latter two options,

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[2] In the United States, producers sell milk to processors for end use either as Class I (fluid), Class II (soft manufactured products such as yogurt or ice cream), Class III (cheese), or Class IV (butter and nonfat dry milk solids).

[3] Cooperatives that generate profits are required to pay a certain percentage of this net income back to members as patronage refunds. However, cooperatives can also maintain a portion of these profits as retained patronage to finance cooperative activities. Members are entitled to redeem this retained patronage at some future date, yet this retained capital does not appreciate in value over time. Thus, at any given time, the retained patronage must be considered as the present value of the redemption at a later date (Cropp et al., 1998).

cooperatives can design risk management strategies, or instruments to offer cooperative members, using the following basic tools: spot or cash market transactions, futures, options, forwards, and swaps.

In the context of (1) above, the effects of the cooperative engaging in active risk management should be evaluated at both the cooperative level and the co-op member level, as risk management strategies may affect the distribution of the cooperative's and the members' profit differently. This is particularly the case if cooperative members choose to forward contract or engage in other risk management opportunities offered as a service of the cooperative.

Following Gloy and Baker (2001), we therefore employ a variety of metrics to evaluate the risk management strategies used at both the cooperative and member levels. Specifically, these measures include: (*a*) expected or mean-level profits, (*b*) standard deviation of expected profits, (*c*) a mean-variance measure (coefficient of variation), (*d*) a certainty equivalent measure (CE), (*e*) value-at-risk at the 5% probability level (VaR), and (*f*) a semivariance measure.

Our starting point for measuring risk is the standard deviation of profits. A primary objective of any risk management strategy should be the reduction in the standard deviation of profits relative to some benchmark, such as a cash-only marketing strategy. However, many risk management strategies are also likely to impact the mean level of profits. Therefore, the coefficient of variation provides information on the first and second moments of the profit distribution in a single, intuitive value that is consistent with expected utility maximization. The coefficient of variation provides a measure of risk relative to returns such that:

$$(3) \quad CV_j = \frac{\sigma_j}{\mu_j},$$

where σ_j is the standard deviation, and μ_j is the expected or mean level of profits resulting from the implementation of risk management strategy j, respectively. In ranking risk management strategies, the measure which produces the smallest coefficient of variation is preferred.[4] Although simple and intuitive, the coefficient of variation suffers from general criticisms of all mean-variance measures—namely, the underlying assumptions of exponential utility and normally distributed profits.

The primary advantage of using a CE measure is its consistency with expected utility maximization. Given its widespread use in modeling the impact of risk aversion on optimal choice under uncertainty, we utilize a negative exponential utility function for calculating the CE of the form:

$$(4) \quad U(\pi) = k_0 - k_1 e^{-\rho\pi},$$

where k_0 and k_1 are constants, and ρ is the coefficient of risk aversion. The utility function in (4) is increasing and concave in profits, π, and exhibits constant absolute risk aversion (CARA).[5] The CE, interpreted as the monetary value an agent would accept in lieu of a risky prospect, is calculated by inverting the utility function (4) and solving for the value of π:

$$(5) \quad CE = -\left(\frac{1}{\rho}\right)\ln\left(\frac{k_0 - E[U(\pi)]}{k_1}\right).$$

CE measures, however, often lack the intuitive appeal that is necessary to communicate risk concepts to managers.

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[4] The Sharpe ratio is often used in place of the traditional coefficient of variation (Gloy and Baker, 2001). The Sharpe ratio is the inverse coefficient of variation of a strategy's returns relative to the returns produced by investment in a risk-free asset. Given the difficulty in defining a consistent risk-free level of profit at both the cooperative and member levels, we focus on the traditional measure of the coefficient of variation to measure mean-variance efficiency.

[5] As an absolute measure of risk aversion, the value of ρ is in dollar units, consistent with the cooperative profit measure.

Further, it is not clear whether expected utility is a good representation of real-world risk management objectives.

Rather, decisions are more likely made according to some form of loss-probability criterion such as VaR (Jorion, 1997; Manfredo and Leuthold, 1999) or a semivariance measure (Turvey and Nayak, 2003; Skelton and Turvey, 1994). VaR is now widely accepted as a measure of a firm's exposure to market-based risk from a variety of sources. Jorion (1997) defines three roles VaR can play in managing risk within an organization: (*a*) as an information reporting tool that efficiently summarizes risk exposures for individuals in key decision roles, (*b*) as a common denominator for comparing risk exposures among projects or investments that compete for scarce financial resources, and (*c*) as a means of comparing performance among a diverse set of enterprises.

Defining risk in this way provides a very intuitive notion of the monetary equivalent of the risk facing a firm as it maps volatility and downside risk into a dollar-equivalent figure. However, VaR is not without its critics. Some maintain VaR provides an inaccurate assessment of risk because the distributions of the relevant risk factors are often fat-tailed or truncated due to the presence of assets possessing nonlinear payoffs such as options (Manfredo and Leuthold, 1999). Further, VaR is defined for a fixed confidence level, but it is difficult to rigorously justify the choice of a particular level relative to another (Gloy and Baker, 2001).

Another downside risk measure, semivariance, is used in addition to VaR. Specifically, semivariance is measured as the expected value of squared deviations below a fixed target level such that:

(6) $E\left\{\left[\min(K - T), 0\right]^2\right\}$,

where K is a random outcome, in this case cooperative or member profits, and T is some fixed reference point (Turvey and Nayak, 2003). Thus, the heuristic justification of using semivariance is the same as VaR—the minimization of downside risk. While VaR is often criticized for providing inaccurate risk assessments of risk in the presence of nonnormal distributions, there are no prior distributional assumptions needed with semivariance. However, the level T at which deviations below are measured still must be justified, but it is not associated with a fixed percentile of the profit distribution like VaR. In many applications this target level is merely the expected return. Similarly, we use average profit measures based on the sample data to establish target levels.

Calculating a number of different measures is necessary because managers tend to differ in terms of their intuitive understanding of risk. While some regard risk in terms of the volatility of returns, others interpret risk as the probability of a loss. At the same time, measures that are easier to calculate and communicate to members and staff, such as VaR, may not be appropriate for the objectives of management or consistent with the economic logic of decision making under risk. Ultimately, if there is strong agreement in the rankings implied by each measure, then using several different measures can provide corroborating evidence in favor of the superiority of one, or even a group of risk management strategies.

Data and Methods

Focus is placed on evaluating the impact of alternative risk management strategies at three levels. First, the distribution of cooperative profits is examined. Second, the impact of the strategies on the distribution of milk revenues at the member level is also considered. Finally, the net profit distribution of the members, after accounting for the variable costs of producing milk, patronage refunds, and the present value of equity redemption, is examined. This value should be considered profit available to cover fixed costs, land, rent, management, and risk.

Cooperative Level

In determining the effectiveness of alternative risk management strategies at the cooperative level, the income statement of a representative dairy cooperative is developed using CoBank financial reporting data. The CoBank financial data are annual, year-end data commonly found in a cooperative's income statement and balance sheet. These data are self-reported by individual co-ops to fulfill required loan documentation, and are also used by CoBank in conducting credit analysis.

Representative dairy cooperatives (SIC 2026) are grouped based on the quantity of milk handled regardless of any particular focus the firm may have such as bargaining only, hard product manufacturing, etc. (Liebrand, 1997). Moreover, given the confidential nature of the CoBank data, the functions of the various dairy cooperatives are not identified in the data set, nor could they be revealed by CoBank. The representative cooperative developed and used in this study is one that markets more than one billion pounds of milk per year.

The CoBank data span from 1992 through 2002, and reflect an unbalanced panel in that some firms do not report every year and/or drop out of the database. Over this sample period, there are a total of 109 yearly observations representing 11 firms in the database. Therefore, the income statement presented in Table 1 reflects the average values of these financial variables over this sample for the group of large dairy co-ops that market more than one billion pounds of milk per year. Table 1 also shows the average amount of milk handled and average total assets for the firms in the sample.

Monte Carlo simulation is used in simulating alternative risk management strategies, and evaluating the effect of these strategies on the distribution of profits.[6] At the cooperative level, profits are defined as *Local Savings*. In essence, *Local Savings* is the same as earnings before taxes (EBT) for investor-owned firms, and provides an indication of profitability of the cooperative before the inclusion of patronage income and other income expense categories.

The baseline strategy used for comparative purposes is cash-only marketing. For this and all other strategies examined, the following assumptions are made to keep the analysis tractable, yet still convey useful probabilistic information related to the risk management strategies used. Consistent with (2) all milk handled by the cooperative goes into the production of nondifferentiated cheese (e.g., cheddar cheese). Second, all the milk handled is assumed to be classified as Class III milk, which is the primary class of milk used to produce cheddar cheese. Third, production technology for cheese (α) is set at 10 pounds of cheese for each hundredweight (cwt) of milk handled (Gould, 1998). Finally, while there is likely some variation in the amount of milk handled by a dairy cooperative, these variations are usually seasonal in nature and are typically familiar to co-op management. Furthermore, it is assumed this representative co-op knows the number of members at any given time, the typical production of milk per member, and subsequently the amount of milk to be marketed. Thus, the quantity of milk marketed, and the amount of cheese produced and marketed, is fixed at the average quantity of milk handled and cheese production technology (see Table 1).

Given these assumptions, *Sales of Processed Goods* in Table 1 is simulated as:

(7) *Sales Processed Goods* =
Cheese Price (\$/lb.) × *Quantity of Cheese Produced* (lbs.),

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[6]The @RISK spreadsheet ad-in program is used in conducting the Monte Carlo simulations.

Table 1. Income Statement, Total Assets, and Milk Handled for Representative Dairy Co-op, 1992–2002 (average values)

Description	
Sales Commodities and Grain	$106,237,407
Sales Processed Goods	**436,649,068**
Sales Supplies	10,543,212
Finance Company Revenue	0
Sales Other	46,720,928
Sales Service Revenue	3,307,442
Sales Adjustments	11,345,892
Net Sales	**592,112,165**
Storage and Handling Revenue + Other Operating Revenue	2,579,028
Total Revenue	**594,691,193**
Cost of Sales Commodities and Grain	117,624,338
Cost of Sales Processed Goods	**285,024,542**
Cost of Sales Supplies	9,591,017
Cost of Funds Finance Co.	0
Cost of Sales Other	28,707,582
Cost of Service Revenue	0
Cost of Sales Depreciation	320,880
COGS	**441,268,359**
Gross Margin	**153,422,834**
Personnel Expense + Benefits Expense	3,100,776
Selling, General, and Administrative	117,439,913
Operating Expenses	20,693,797
Lease Rent Expense	536,599
Depreciation and Depletion	4,314,244
Amortization	61,550
Total Operating Expenses	146,146,879
Operating Profit (EBT)	**7,275,955**
Interest Finance Charge Income	312,800
Interest Expense	1,404,053
Local Savings	**$6,184,702**
Total Assets	$115,254,594
N: Yearly Observations	109
Number of Firms	11
Quantity of Milk Handled (cwt)	126,666,855

Source: Developed by authors using CoBank financial reporting data.

and the *Cost of Sales Processed Goods* is calculated as:

(8) *Cost of Sales Processed Goods* = *Class III Price* ($/cwt) × *Average Amount of Milk Handled* (cwt).

In the Monte Carlo simulation, the price of cheddar cheese is designated as a stochastic input variable. The historical data used to fit the distribution of cheese price is the monthly historical cheddar cheese price (40-pound blocks, National Cheese Exchange/Chicago Mercantile

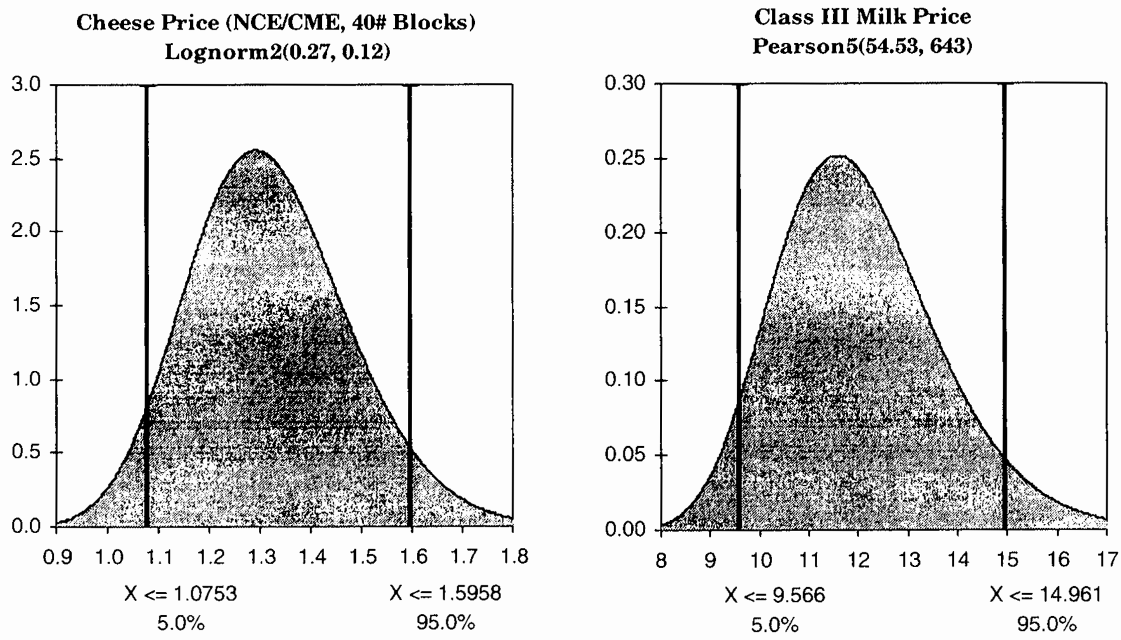

Figure 1. Fitted Probability Density Functions for Stochastic Inputs: Monthly Cheddar Cheese and Class III Milk Prices, 1992–2002

Exchange, $/pound) from 1990–2002. These data are taken from the U.S. Department of Agriculture/Agricultural Marketing Service (USDA/AMS) *Dairy Market News*. Also, the Class III milk price is designated as a stochastic input variable in the simulation. The distribution for Class III price is fit using the monthly historical announced Class III price from 1990–2002, with data derived from the University of Wisconsin Dairy Marketing and Risk Management Program.[7]

The appropriate distribution fit to these two data sets was determined using the Kolmogorov-Smirnov test with maximum-likelihood methods (Massey, 1951). The distribution of monthly cheese prices is found to be best described as a lognormal distribution where $\mu = 0.27$ and $\sigma = 0.12$, and the best fit distribution for Class III milk follows the Pearson-V distribution where $\alpha = 54.53$ and $\beta = 643$. The probability density functions of these input distributions are illustrated in Figure 1.

Furthermore, the correlation between historical Class III milk price and cheddar cheese prices is quite high (0.94). This is not surprising given that the monthly average National Agricultural Statistics Service (NASS) survey price for cheddar cheese is used in deriving the monthly Class III formula price. Thus each draw from respective input distributions is constrained to reflect this correlation. Accordingly, *Local Savings* in Table 1 is a function of random sales and cost of sales [(7) and (8)], and so in turn is also a random variable.

Milk Revenue

The distribution of milk revenue is examined from the perspective of cooperative member-producers. Since information on individual cooperative members was not available, we examine the milk revenue received by all cooperative

[7] Prior to January 2000, the basic formula price (BFP) is used in this data set. To obtain a representative history of milk prices that include both high and low price extremes, the price series which contains the BFP price is needed.

members collectively. For purposes of the simulation, the price received for milk at the producer level is assumed to be the Class III price paid by the cooperative. However, the actual price received by an individual member, also known as the member's mailbox price for milk implied from the member's monthly milk check, is likely to be different than the Class III price. The implied price from the milk check, calculated as the monthly milk revenue divided by volume marketed, reflects the announced Class III price, a producer price differential, and other adjustment factors such as hauling charges and quality/volume discounts and premiums. Provided the milk shipped by a member tests at least 3.5% butterfat, 2.99% protein, and 5.6% solids, the producer will receive the Class III price plus appropriate adjustments.

Because of this, Thraen (2002) argues that the difference between the mailbox price and the Class III price does not reflect basis risk per se, since the producer price differential is a function of classified pricing as set by Federal Milk Marketing orders, and that "location adjustments, quality premiums, [and] volume premiums are generally offset by hauling charges (usually paid by the producer)..." (p. 9). Therefore, the only truly hedgeable portion of milk revenue is the announced Class III price, which is reflected in all members' mailbox price.

Given the above, the milk revenue attributed to all cooperative members providing milk to the cooperative is simulated as:

(9) *Milk Revenue* = *Class III Price* (\$/cwt) × *Average Amount of Milk Handled* (cwt),

where the *Average Amount of Milk Handled* is the same as in the *Cost of Sales Processed Goods* in expression (8). Considering *Milk Revenue* in (9), focus is placed on how various risk management strategies or instruments used by the cooperative, or offered to members by the cooperative, impact the distribution of members' collective milk revenues.

Cooperative Member Profits

Finally, the distribution of cooperative member profits is examined. The collective profits received by cooperative members following (1) are simulated as:

(10) *Member Profits* = *Milk Revenue* + *Patronage Refunds* + *Present Value of Equity Redemptions* – *Variable Costs of Production.*

Patronage Refunds are calculated as 20% of *Local Savings* generated by the cooperative, which is consistent with typical payout structures (Cropp et al., 1998). The remaining 80% of annual *Local Savings* is assumed to be used for internal equity financing and subject to equity redemption by individual members. Because members will only realize equity redemptions at a future date, the equity redemption value must be considered as the present value of equity redemptions (Cropp et al.).

In calculating the *Present Value of Equity* in (10), a discount rate of 5% (somewhat higher than prevailing short-term interest rates at the time to compensate for risks of dairy farming) and a time line of five years are used. *Variable Costs of Production* are \$11.18/cwt, consistent with the national average variable costs of production for the years 1992–2002 for milk in the United States as reported by the USDA/NASS. Since the cooperative is an extension of an individual member's business, the actual distribution of *Member Profits* resulting from risk management activities engaged in or offered by the co-op should be of interest.

Risk Management Strategies

For each strategy examined, the number of iterations used in the Monte Carlo simulation is set at 5,000. This provides a sufficient number of random draws from the input distributions to yield meaningful

Table 2. Risk Management Strategies Simulated (cheese price/milk price)

Strategy Number	Description of Simulated Strategies
1	Cash cheese / Cash milk
2	Forward contract cheese / Cash milk
3	Swap cheese / Cash milk
4	Cash cheese / Co-op buys Class III milk futures (IOF strategy)
5	Cash cheese / Co-op buys Class III milk call options (IOF strategy)
6	Cash cheese / Co-op offers forward contract to producers and buys at-the-money put options on Class III milk futures to hedge forward; producers routinely choose forward contract
7	Cash cheese / Co-op offers forward contract to producers and buys at-the-money put options on Class III milk futures to hedge forward; producers choose forward if forward price > variable costs of production
8	Cash cheese / Co-op offers forward contract to producers and sells Class III milk futures to hedge forward; producers choose forward if forward price > variable costs of production
9	Forward contract cheese / Co-op offers producers forward contract derived from forward cheese price; producers routinely accept forward contract
10	Cash cheese / Co-op offers producers 12-month contract which is the average price of the Class III milk futures price for the prevailing 12 months
11	Cash cheese / Co-op offers producers minimum price contract; producers routinely choose forward contract and pay a premium for the contract equivalent to the premium on at-the-money put option on Class III milk futures
12	Cash cheese / Co-op offers producers minimum price contract by purchasing at-the-money put options on Class III milk futures on producers' behalf; producers routinely choose forward contract and pay the premium for the put option
13	Cash cheese / Co-op offers a menu of risk management strategies to producers; milk marketed through co-op in the following proportions: 50% strategy 1, 25% strategy 8, and 25% strategy 12
14	Co-op implements various strategies in managing cheese prices in the following proportions: 50% strategy 1, 25% strategy 2, and 25% strategy 3 / Co-op offers menu of risk management strategies to producers commensurate with strategy 13

and consistent distributions of profits at both the cooperative and member levels. Furthermore, incorporating 5,000 iterations allows the defined profit levels to be exposed to extreme draws of the stochastic inputs of Class III milk and cheddar cheese prices represented in the described input distributions. In the simulation, prices of both Class III milk and cheddar cheese are drawn such that they follow a random walk where $P_t = P_{t-1} - e_t$. All risk management strategies examined assume a monthly planning horizon—i.e., all strategies are placed and lifted on a monthly basis. While it is indeed the case that milk flow and cheese production/sales through a cooperative are continuous, the monthly planning horizon is adequately short to reflect the continuous nature of dairy production, is consistent with how milk producers are paid, and allows for the model to remain tractable. Therefore, it is a reasonable representation for purposes of this simulation.

The average of the monthly prices of cheese (milk) are then multiplied by the annual volumes of cheese (milk) that flow through the representative cooperative to come to values of cheese (milk) used in calculating *Local Savings* at the co-op level and *Milk Revenue* and *Member Profits* at the cooperative member level.

All of the risk management strategies simulated originate at the cooperative level. That is, strategies are directly incorporated by the cooperative, or risk management tools are designed by the cooperative and offered to members. Table 2 summarizes and briefly describes the specific strategies used, with each strategy being assigned a number. Strategy 1 describes the benchmark, cash-only marketing strategy as illustrated in (7) and (8). Strategies 2 and 3 focus only on managing the risk of cheddar cheese price at the cooperative level. Strategies 4 and 5 represent efforts by the cooperative to manage the price of milk similar to that of a competing investor-owned firm (IOF), treating the price of milk as an input into the production process.

Considering the above, strategies 2–5 will only impact the distribution of *Local Savings* and subsequently *Member Profits* through patronage refunds and equity redemptions—not *Member Revenue* directly. Strategies 6–12 represent strategies offered to cooperative members as a means of managing the risk of the members' milk price. Depending on the specific structure of these strategies, *Local Savings*, *Milk Revenue*, and *Member Profits* all may be affected.

Strategies 13 and 14 are probably the most realistic strategies simulated as they attempt to consider a choice of risk management strategies. Specifically, the cooperative is likely to engage in and/or offer several different risk management strategies throughout the marketing year, and producers may differ in their adoption of risk management strategies offered by the cooperative. Indeed, given the diverse membership of a large dairy cooperative, some members are likely to seek out the use of risk management strategies provided by the cooperative, some may decide to manage risks on their own, while still others may simply be content with a cash-only strategy. Each of the simulated risk management strategies is further detailed below, and also described in Table 2.

Strategy 2 is a forward-contracting arrangement for cheese where the cooperative arranges to (say) deliver cheese to a supermarket chain or other end user of cheddar cheese such as a food manufacturer (Gould, 1998), where:

(11) *Contract Price of Cheese* (\$/lb.)

$$= (\textit{Beginning Class III Price} + \textit{Margin})/10,$$

and *Margin* reflects the operating margin on processing cheese equal to \$0.12/pound (Gould, 1998).[8]

The next strategy examined (strategy 3) is that of a revenue swap. The revenue swap is structured as follows. First, it is assumed that two counterparties agree upon a set amount of cheese to be sold/purchased at a fixed price. Both the quantity of the cheese sold/purchased and price are set at the historical average from 1992–2002. Therefore, a benchmark value for cheese revenue is established. Furthermore, the counterparties involved are assumed to have opposite economic interests. For example, a manufacturer of frozen pizzas is concerned with price of cheese increasing, while the cooperative is concerned with declining cheese prices.

Thus, when cheese revenue to the cooperative is less than the benchmark value, the cooperative will receive a payment from the counterparty equivalent to the difference between benchmark revenue and realized revenue. Similarly, the counterparty will receive a payment from the cooperative if cheese revenue is greater than the benchmark value.

While Class III prices are announced monthly, as with most swap arrangements there would be a designated time(s) within a designated time frame to exchange cash flows (e.g., yearly exchange of cash flows).

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[8] Depending on the specific cooperative and market conditions, this margin could potentially be greater or less than \$0.12/pound. However, this fixed margin is adequate for determining the effects of forward-contracting arrangements on *Local Savings*.

The revenue from the swap strategy is defined as:

(12) *Revenue* = *Cheese Price* ($/lb.) × *Cheese Sold* (lbs.) + [*Benchmark Value* – (*Cheese Price* ($/lb.) × *Cheese Sold* (lbs.))],

where the *Benchmark Value* is equal to the historical average price of cheddar cheese multiplied by the average amount of cheese produced by the cooperative on an annual basis. For both strategies 2 and 3, the raw milk used in producing this cheese is assumed not yet in the possession of the cooperative. Thus, while the output price of cheddar is fixed, the risk to the cooperative is that the price of milk will actually increase at the time the contract must be fulfilled (cheese produced and delivered), thereby squeezing cooperative-level profits.

Strategies 4–6 focus on managing the variability of the Class III milk price only. While this is not unlike the perspective commonly taken by investor-owned firms, lower input costs to the cooperative, holding revenue constant, means higher profits at the cooperative level—profits that may eventually be returned to member-producers. Most of these strategies incorporate the use of Class III milk futures which are listed on the Chicago Mercantile Exchange (CME). The Class III futures price reflects traders' expectations of the "announced" Class III price for a particular delivery month, because at expiration, the Class III futures converge to the announced Class III price. Given this, as well as the relatively short trading history of the CME milk contracts, the historical announced Class III price is used as a proxy for Class III futures.

Allowing the historical announced Class III price to be used as a proxy for Class III futures implicitly assumes that basis, and subsequently basis risks realized from hedging with Class III milk futures, is effectively zero. While this notion at first appears naive, the arguments offered by Thraen (2002), discussed previously, make a solid case that the only hedgeable portion of the final milk check paid to milk producers is the Class III components. In the Monte Carlo simulation, a beginning and ending Class III price distribution is designated to proxy both beginning and ending futures. While these input distributions have the same parameters, they are drawn independently in the simulation following a random walk where $P_t = P_{t-1} - e_t$. Hence, the ending futures price in one month is the beginning futures price in the following month.

Strategy 4 is a routine futures hedge of Class III milk inputs, similar to what might be used by an investor-owned milk processing firm. To protect against increasing milk prices, the cooperative takes a long position in Class III futures prior to taking possession and paying members for their milk. Hence, the routine futures strategy is defined as:

(13) *Final Price Paid for Milk* = *Ending Class III Price* + [*Beginning Class III Price* (long) – *Ending Class III Price* (short)].

If *Ending Class III Price* is greater than the *Beginning Class III Price*, the cooperative will make a profit on the hedge, reducing the final price paid for milk. Given the assumption that the Class III price is equal to CME futures (zero basis), this strategy provides a perfect hedge of the Class III components of the cooperative's milk payment to its members (Thraen, 2002). Hence, any savings achieved by the cooperative through this strategy can be passed on to its members. *Final Price Paid for Milk* defined in (13) replaces the *Class III Price* in (8) to yield the *Cost of Sales Processed Goods*, and subsequently *Local Savings*.

Options, however, provide a way of taking advantage of price protection only when needed. The options strategy simulated, strategy 5, involves the purchase of at-the-money call options to set a ceiling price for milk, providing protection against price increases, with the potential to realize decreases in the price of milk should they occur. Again, this strategy assumes the cooperative behaves like an investor-owned milk processing firm. The following defines the final price paid for milk using the at-the-money call option strategy:

(14a) If *Strike* < *Ending Class III Price*, then:

Final Price Paid for Milk = *Ending Class III Price* + (*Strike* – *Ending Class III Price* + *Option Premium*),

and

(14b) if *Strike* ≥ *Ending Class III Price*, then:

Final Price Paid for Milk = *Ending Class III Price* + *Option Premium*.

Option premiums are simulated within the Monte Carlo simulation using Black's (1976) option pricing model.[9] The inputs into this option pricing formula include the strike price, the underlying futures price, the time to expiration, the risk-free rate of interest, and the volatility of the underlying futures price. Given that at-the-money options are examined, the strike price is equal to the *Beginning Class III Price*. Since the risk-free rate of interest has a very minor influence on option premiums, it is set at a fixed 3%, which is reasonably consistent with interest rates in the later part of the sample period. The volatility used in the option pricing model is the historical annualized volatility of monthly Class III milk prices from 1992–2002 (27% annualized volatility), and the time to expiration is set at 30 days.

Futures and options on Class III milk also allow cooperatives to hedge forward contracts written for their members. Providing a forward contract allows the co-op member to realize a fixed price of milk, thereby helping to reduce the uncertainty of revenue. The cooperative, by providing forward contracts to its members, essentially serves as a financial intermediary. A typical forward contract consists of the co-op offering a fixed forward price to the member and offsetting this risk by selling Class III futures (Gould, 1998).

Given that basis risk is zero in the simulation (Thraen, 2002), and assuming the cooperative routinely provides its members with a forward contract, in the long run the final price paid for milk by the co-op and received by the members with the forward contract will always be the same as a cash-only strategy, unless the cooperative explicitly charges for this service and/or adds a fixed margin into the forward contract price. Therefore, a milk producer is unlikely to routinely take a forward contract unless the forward contract provides a price that allows the producer to lock in a positive profit margin. So, the decision to forward contract milk is a selective one.

To circumvent the simulation result that routine forward contracting yields the same distributions as a cash-only strategy, strategies 6, 7, and 8 are employed. Under strategy 6, the producer routinely takes the forward contract offered by the cooperative, but instead of selling futures to offset the forward contract, the cooperative purchases at-the-money put options and deducts the option premium from the forward price.

In this case, the member directly finances the option hedge by taking a discount in the forward price equal to the put option premium. Put option premiums are calculated similarly to the call option premiums described previously. Still, the co-op member receives a fixed price for his or her milk, and allows the cooperative to manage the risk through the purchase of a

[9] The Financial CAD software package, along with @RISK, was used to estimate the option premiums in the Monte Carlo simulation.

put option.[10] Therefore, the final price paid for milk by the cooperative using strategy 6 is defined as follows:

(15a) If *Ending Class III Price* < *Strike*, then:

Final Price Paid for Milk = *Forward Price Offered* – (*Strike* – *Ending Class III Price*) + *Option Premium*,

and

(15b) if *Ending Class III Price* ≥ *Strike*, then:

Final Price Paid for Milk = *Forward Price Offered* + *Option Premium*,

and the producer receives the forward price offered, defined as:

(16) *Forward Price Offered* = *Beginning Class III Price* – *Option Premium*.

Strategy 7 is similar to 6, but this strategy assumes that members will only take a forward contract offered if the forward price is greater than their variable costs of production. Therefore, if the forward contract price described in (16) is greater than cost of production, the producer will take the forward contract. If not, the producer takes the market price.

Strategy 8 also allows the producer-member to choose whether to take the forward contract. This strategy differs from the forward contracts defined earlier since short futures positions are entered when the cooperative offers the forward contract. Again, if the forward price offered is greater than the costs of production, the producer will take the forward price, and the cooperative will simultaneously enter a short position in the milk futures market. In both strategies 7 and 8, the variable cost of production is $11.80 per cwt, which is the U.S. average variable cost of production for dairy farms from 1992–2002, as reported by USDA/NASS.

Two other types of forward contracts are also simulated. These contracts are similar to those offered to the members of Alto Dairy, and are described on the cooperative's website (see footnote 1). The first of these, strategy 9, is based on a forward price for cheese. If the cooperative enters a forward contract with a cheese customer, the cooperative should then be able to offer a forward milk price to its members derived from the cheese price assuming the previously stated production technology. Assuming cooperative members routinely accept this forward price, the cooperative knows the cheese price and milk price it must pay producers, securing a profit margin at the cooperative level.

The second type of forward contract, strategy 10, is a 12-month forward contract where producers can lock in a given milk price for an entire calendar year. Following a similar procedure to that of Alto Dairy, this forward price is arrived at by taking the average of the beginning Class III prices for months 1–12 in the simulation. Strategy 10 is a routine strategy, i.e., it is assumed the producer will routinely take the 12-month contract when offered.

The final type of milk contracts offered to members by the cooperative, strategies 11 and 12, are minimum price contracts. In essence, offering a minimum price contract to member-producers is akin to offering them a put option. The member will receive the minimum milk price offered, but can also benefit from gains in the market price above that of the minimum. The only differences between strategies 11

[10] In results separate from those presented for this strategy, it was found that offering a forward price less the option premium provided a larger *Local Savings* than not deducting the options price from the forward contract price. However, this may be just an issue with regard to transfer of funds since a larger *Local Savings* would imply a larger distribution of cooperative profits back to the members. So in many respects, these two strategies should be a "wash," and preference toward a particular strategy would be more related to cash flow preferences of the individual members (e.g., finance the option at the time of the forward contract, or allow the cooperative to finance it, and potentially receive a smaller distribution of excess profits ex post).

and 12 are the specifics of how the cooperative offers the contract.

With strategy 11, the cooperative in essence sells a naked option to the producers whereby the floor price is guaranteed without offsetting the risk in the futures market or options market. In offering this contract, the cooperative does charge a premium, assumed here to be analogous to the put option premium described earlier. Under strategy 11, the final price realized at the cooperative level and received by members is as follows:

(17a) If *Ending Class III Price* < *Minimum Price Contracted*, then:

Final Price Paid (Received) for Milk = Minimum Price Contracted – Premium,

and

(17b) if *Ending Class III Price* ≥ *Minimum Price Contract*, then:

Final Price Paid (Received) for Milk = Ending Class III Price – Premium.

Strategy 12 is similar to strategy 11, but here the cooperative purchases an at-the-money put option on behalf of the producer-member, with the member paying the premium. So, for strategy 12, the final milk price paid by the cooperative is the same as in (15) and the final price received from the members' perspective is the same as in (17).

Simulating each of the above strategies should provide insight into how they augment the distribution of *Local Savings*, members' *Milk Revenue*, and subsequently *Member Profits*. However, choices can be made at both the cooperative and member levels as to the mix of risk management strategies that may be adopted, or not adopted, at any given time.

Consequently, two strategies are considered which allow for multiple strategies to be implemented. A "members' choice" strategy, strategy 13, assumes a proportion of the total quantity of milk marketed by co-op members is marketed under one of the above outlined strategies: 50% under the cash-only strategy 1, 25% with strategy 8 (forward contract), and 25% with strategy 12 (minimum price contract). Strategy 14 assumes the cooperative is managing the risk of some proportion of its cheese output (50% strategy 1, cash only; 25% strategy 2, forward contract; and 25% strategy 3, swap) while cooperative members are choosing among risk management strategies the same as outlined in strategy 13.

These combination strategies are fairly realistic given that neither the cooperative nor individual members are likely to routinely incorporate any of the previously examined strategies. Specifically, some cooperative members are likely to participate while others are not, and there will be times when the cooperative is actively involved in managing risks, and times when it is not. Thus these combination strategies may provide a more realistic picture of financial performance, at both the cooperative and member levels, resulting from the implementation of various risk management strategies.

Results

Rankings for *Local Savings*, *Milk Revenue*, and *Member Profits* under each of the evaluation criteria (mean profit, standard deviation, coefficient of variation, certainty equivalent, value-at-risk, and semivariance) are reported in Tables 3–5, respectively.

Local Savings

For *Local Savings*, there was some inconsistency in rankings across evaluation criteria (Table 3). The strategies that produced the smallest risk (standard deviation) of *Local Savings* were strategies 1, 8, 12, and 13 with a standard deviation of approximately $20.7 million (each of these strategies produces the same outcome).

Table 3. Rankings of Alternative Risk Management Strategies: Local Savings

Strategy Number	Rank	Mean ($)	Rank	Standard Deviation ($)	Rank	CV	Rank	VaR ($)	Rank	CE ($)	Rank	Semi-variance[a] ($)
1	7*	7,267,181	1*	20,647,677	4*	2.8412	4*	-26,691,423	4*	2,785,195	4*	14,138,436
2	5	8,514,702	3	24,343,412	5	2.8590	6	-31,434,092	5	2,350,349	6	15,839,208
3	10	6,726,975	8	59,557,436	8	8.8535	8	-94,035,992	8	-32,278,470	8	42,760,214
4	9	7,140,419	4	30,757,795	7	4.3076	7	-45,360,512	7	-2,826,342	7	21,437,894
5	3	49,573,664	6	36,743,218	3	0.7412	3	-7,732,171	3	36,503,306	3	6,618,706
6	1	198,720,423	7	36,992,520	1	0.1862	1	141,409,308	1	185,592,043	1	0
7	2	72,266,118	5	33,123,093	2	0.4583	2	22,566,689	2	61,885,674	2	983,591
8	7*	7,267,181	1*	20,647,677	4*	2.8412	4*	-26,691,423	4*	2,785,195	4*	14,138,436
9	4	8,755,754	10	90,460,450	9	10.3315	10	-147,772,538	10	-88,844,369	10	64,693,830
10	8	7,161,551	9	83,446,283	10	11.6520	9	-130,706,553	9	-65,689,906	9	58,444,464
11	11	-34,643,214	11	101,168,192	11	-2.9203	11	-207,825,972	11	-161,736,571	11	98,306,174
12	7*	7,267,181	1*	20,647,677	4*	2.8412	4*	-26,691,423	4*	2,785,195	4*	14,138,436
13	7*	7,267,181	1*	20,647,677	4*	2.8412	4*	-26,691,423	4*	2,785,195	4*	14,138,436
14	6	7,444,010	2	22,257,714	6	2.9900	5	-30,222,249	6	2,134,439	5	15,379,690

* Denotes identical rank values within the same column.

[a] The threshold level, *T*, of *Local Savings* used in calculating semivariance [equation (6)] is $6,184,702, which is the average level of *Local Savings* for the representative cooperative over the sample period 1992–2002. Semivarance reported in the table is the square root of the semivariance measure defined in equation (6). The square root was taken to express the semivariance in dollar units.

Notably, no strategy produces a smaller standard deviation of *Local Savings* than cash marketing of cheese and milk (strategy 1). The offering of certain risk management tools to cooperative members, such as forward contracts, does not increase the standard deviation relative to strategy 1. For instance, strategy 8—where forward contracts are routinely offered, yet members only choose when the forward price is greater than their variable costs—yields the same *Local Savings* standard deviation as strategy 1. However, when also considering the mean level of *Local Savings* in the context of the coefficient of variation (CV), strategies 1, 8, 12, and 13 fall in rank to fourth place, with a coefficient of variation equal to 2.8412. Based on the coefficient of variation, strategy 6 ranks first at 0.1862, strategy 7 second at 0.4583, and strategy 5 third at 0.7412. Both strategies 6 and 7 incorporate the use of put options to enable the offering of a forward milk price to members, where the only difference is that strategy 7 allows members to choose whether to enter the forward contract.

Interestingly, when considering the other ranking criteria of VaR, CE, and semivariance, the rankings remained mostly consistent. Strategy 6 produced the largest VaR at $141.4 million, which suggests that under strategy 6, *Local Savings* less than this would only be realized less than 5% of the time. Additionally, strategy 6 produced the highest level of CE, likely driven by the fact that strategy 6 also produces the highest level of expected (mean) *Local Savings*. Moreover, strategy 6 produced a zero semivariance because, under this strategy, *Local Savings* did not dip below the predetermined threshold level established for calculating the semivariance measure.

The rankings are similar for strategy 7, yet the magnitudes of the VaR, CE, and semivariance are different. This is explained by the fact that under strategy 7, forward contracts are only accepted if the forward price is greater than variable costs of production. For instance, the VaR for strategy 7 is $22.6 million, which is approximately 85% smaller than that produced by strategy 6. Consequently, with strategy 7, *Local Savings* is expected to be less than $22.6 million less than 5% of the time. Similar magnitude differences are found with the CE, while the semivariance measure is positive yet still considerably smaller than those produced by the other strategies.

While it can be argued that strategies 6 and 7 are not the best in terms of reducing overall standard deviation (ranked seventh and fifth based on standard deviation, respectively) relative to the benchmark strategy (strategy 1), a considerable improvement is made with these strategies in terms of downside risk as measured by VaR and semivariance. In fact, the VaR for strategy 1, and subsequently strategies 8, 12, and 13 as well, is -$26.7 million. Hence, the cooperative under each of these strategies would expect to have losses of approximately $26.7 million about 5% of the time.

Strategy 5, another strategy incorporating the use of options, ranked third behind strategies 6 and 7 based on the mean level of *Local Savings*, coefficient of variation, VaR, CE, and semivariance. While strategy 5 is clearly not the most risk-reducing in terms of standard deviation, considerable improvement is made in the VaR and semivariance measures relative to strategy 1. In terms of a 5% VaR, losses are only expected to exceed -$7.7 million less than 5% of the time, while this number is considerably higher (at -$26.7 million) under strategies 1, 8, 12, and 13, all of which actually had the smallest standard deviation.

Strategy 5 also has a considerably smaller semivariance, almost half that of strategy 1 ($6.6 million vs. $14.1 million). Interestingly, this strategy suggests there is some benefit in the cooperative acting like an IOF in terms of managing risks at the cooperative level—i.e., the cooperative can improve its risk/return profile, and reduce downside risk, by treating milk solely as an input to the cooperative and managing its price variability through the purchase of call options (setting a ceiling for the price of milk to the cooperative). Again, this is likely a function of improvement in the mean level of *Local Savings*, which is further demonstrated through the CE measure of $36.5 million relative to the CE under strategy 1 of $2.8 million. Benefits in terms of downside risk reduction, as well as an improvement in the mean of *Local Savings*, translates into benefits to co-op members as *Local Savings* ultimately returned to members through patronage refunds and/or equity redemptions.

A major practical hindrance to any risk management strategy which necessitates either the sale or purchase of options on Class III milk futures, such as strategies 6, 7, 5, and 12, is the liquidity of the CME's milk options market. Given the sheer volume of milk marketed by this representative large dairy cooperative (126 million cwt), and assuming full hedging on a volume basis (200,000 pounds of milk per CME contract), approximately 63,000 options contracts would need to be traded under the simulation scenarios. Clearly, with a total volume of 85,713 option contracts (combined puts and calls) for 2006, implementing any wholesale risk management strategy relying on options positions becomes difficult under current market liquidity conditions. It is perhaps feasible that over-the-counter contracts would be entered to fill the void in this liquidity, yet the development and depth of the over-the-counter dairy markets is unknown. So while the incorporation of these strategies may first appear appealing to cooperative managers, there are practical constraints to their implementation.

In offering forward contracts to members, strategy 8 appears to be a more feasible choice. The total volume of Class III futures traded (all contracts) was approximately 225,000 for 2006. While the liquidity in the Class III futures market is adequate, and has been growing over time, periodic liquidity constraints in the Class III futures market may still hamper the ability to execute this strategy efficiently.

Given the above findings, strategies focusing more on managing the price risk of cheese at the cooperative level may be more feasible at reducing the variability of *Local Savings*. Namely, strategy 2, which relies on forward contracting cheese, provides the third lowest standard deviation after strategies 1, 8, 12, 13, and 14, and ranks either fifth or sixth based on all other criteria. Strategy 11, the offering of a minimum price milk contract to members (akin to selling a naked option on a strike milk price) performs worst across all criteria.

Although it first appears that little improvement in *Local Savings* can be made at managing the variability of cheese prices at the cooperative level, the results of strategy 14 show some promise. Strategy 14, which assumes that different proportions of cheese volume are marketed via strategies 1–3, and milk is purchased incorporating a combination of strategies 1, 8, and 12, has the second lowest standard deviation of *Local Savings* after strategies 1, 8, 12, and 13. Strategy 14 is unique in that it probably represents the most realistic situation—that is, risk management strategies incorporated by the cooperative, and those offered by the cooperative and implemented by members, are likely to vary. In particular, there are times when the decision to not manage risk is optimal. Indeed, getting the most out of a selective risk management strategy requires considerable price forecasting skills, or luck, especially in the presence of efficient markets. Still, there may be times when the market is providing a "good price" relative to costs of production—a situation which is simulated under strategies 7 and 8.

Probably the most interesting results from the examination of *Local Savings* is the notion that risk management instruments can be designed and offered to cooperative members yielding little impact on the cooperative's financial position. This is most notably seen by the results of strategies 8, 12, and 13, which yield the same numbers as the cash-only strategy 1. Focusing on strategy 8, for instance, the offering of forward contracts to members, and hedging the forward contract in the Class III futures market, does not change the distribution of *Local Savings* relative to cash-only marketing. Furthermore, offering a menu of milk price risk management tools to members, as simulated in strategy 13, yields the same distribution statistics as with strategy 1.

While this is very appealing, especially if market risk management services are viewed as a way to attract and maintain cooperative membership, the results presented do not take into consideration transactions costs, and assume that option premiums are passed on to the member in cases where options are used in creating the forward or minimum price contract. Indeed, as long as these costs are borne by the member directly, and not the cooperative, the distribution of *Local Savings* under strategy 13 will be the same as for the cash-only strategy. Nevertheless, how the strategies identified in Table 2 perform at the producer-member level is important to consider before any wholesale recommendations can be made.

Milk Revenue

Table 4 presents the rankings of the risk management strategies outlined in Table 2 from the perspective of how these strategies affect the distribution of co-op member *Milk Revenue*. Obviously each member in the cooperative will have different volumes of milk marketed through the cooperative, and each is likely to make his or her own decision regarding the adoption of any risk management products offered through the cooperative. However, these results shed light on how cooperative risk management practices may impact member *Milk Revenue*.

Considering standard deviation only, strategy 7 ranked first at $56.4 million, and strategy 6 a close second at $56.5 million. Both of these strategies rely on the use of put options by the cooperative in offering forward contracts to members. Implementing these strategies reduced the standard deviation relative to the cash-only strategy 1 by approximately $3 million, and also ranked highly among most of the criteria for *Local Savings* discussed previously.

Strategies 13 and 14, the combination strategies, yielded the same outcomes across all ranking criteria for *Milk Revenue*, and yielded the third smallest standard deviation of *Milk Revenue* at $58.3 million—approximately $1 million less than strategy 1. Strategies 1–5 all maintain the same rankings across ranking criteria.

Interestingly, based on standard deviation only, strategy 10 (ranked sixth), strategy 8 (ranked seventh), strategy 12 (ranked eighth), and strategy 11 (ranked ninth) actually increased the standard deviation of *Milk Revenue* relative to strategy 1. Therefore, all other risk management strategies either improved or provided the same standard deviation as strategy 1. One of the more curious results is the poor performance of strategies 10, 8, 12, and 11. Surprisingly, routinely taking a minimum price contract (strategies 11 and 12) or a forward price when the forward milk price offered is greater than variable costs of milk production, actually increased standard deviation of milk revenue relative to cash only. The increase is substantial, ranging from an increase of approximately $1 million for strategy 10 (ranked sixth) to $12 million for strategy 11 (ranked ninth and last).

The coefficient of variation, VaR, CE, and semivariance provide additional insight into how the simulated strategies affect the distribution of *Milk Revenue*. Based on coefficient of variation, strategies 13 and 14 have the lowest at 0.0379, i.e., these two strategies provide the lowest standard deviation relative to the mean. Strategy 9, which incorporates the offering of forward contracts based on cheese prices, ranks second based on coefficient of variation. Notably, strategies 6 and 7, which performed best based on standard deviation, performed poorly when

Table 4. Rankings of Alternative Risk Management Strategies: Member Milk Revenue

Strategy Number	Rank	Mean ($000s)	Rank	Standard Deviation ($000s)	Rank	CV	Rank	VaR ($000s)	Rank	CE ($000s)	Rank	Semi-variance[a] ($000s)
1	7*	1,520,903	5*	59,557	5*	0.0392	6*	1,425,112	7*	1,519,724	5*	4,810
2	7*	1,520,903	5*	59,557	5*	0.0392	6*	1,425,112	7*	1,519,724	5*	4,810
3	7*	1,520,903	5*	59,557	5*	0.0392	6*	1,425,112	7*	1,519,724	5*	4,810
4	7*	1,520,903	5*	59,557	5*	0.0392	6*	1,425,112	7*	1,519,724	5*	4,810
5	7*	1,520,903	5*	59,557	5*	0.0392	6*	1,425,112	7*	1,519,724	5*	4,810
6	9	1,446,377	2	56,501	4	0.0391	9	1,354,103	9	1,445,315	9	23,948
7	8	1,446,431	1	56,377	3	0.0390	8	1,354,660	8	1,445,373	8	23,901
8	1	1,592,888	7	64,325	7	0.0404	1	1,492,672	1	1,591,514	1	1,312
9	5	1,521,030	4	59,074	2	0.0388	5	1,425,568	5	1,519,869	7	5,160
10	6	1,521,009	6	60,365	6	0.0397	7	1,423,609	6	1,519,797	6	5,101
11	2	1,563,228	9	71,208	9	0.0456	2	1,452,386	2	1,561,545	3	3,013
12	3	1,563,118	8	71,026	8	0.0454	3	1,451,899	3	1,561,444	4	3,104
13	4*	1,538,900	3*	58,316	1*	0.0379	4*	1,445,640	4*	1,537,768	2*	2,823
14	4*	1,538,900	3*	58,316	1*	0.0379	4*	1,445,640	4*	1,537,768	2*	2,823

* Denotes identical rank values within the same column.

[a] The threshold level, T, of *Milk Revenue* used in calculating semivariance [equation (6)] is $1.146 billion, which is calculated by taking $11.18/cwt (the average price of milk over the sample period 1992–2002) times the average amount of milk marketed through the cooperative, 126,666,855 cwt. Semivarance reported in the table is the square root of the semivariance measure defined in equation (6). The square root was taken to express the semivariance in dollar units.

considering VaR, CE, and semivariance. In terms of VaR and semivariance, strategies 6 and 7 provide overall reduction in the standard deviation of members' milk revenue, but considerably increase downside risk relative to the cash-only strategy.

In contrast, while ranking relatively low based on risk reduction through standard deviation, strategy 8—forward contracting when price is greater than variable costs of milk production—ranked first based on VaR, CE, and semivariance. This strategy was particularly effective in reducing downside risk as measured by VaR and semivariance. The VaR is $1.493 billion under strategy 8, while it is $1.425 billion under the cash-only strategy 1 (as well as strategies 2–5). So, under strategy 8, there is only a 5% chance that total member *Milk Revenue* would fall below $1.493 billion during a given year, while there is a 5% chance it would go below $1.425 billion under the cash-only strategy. This finding suggests a reduction in the downside risk of milk revenue as measured by VaR of approximately $67 million. Further, the semivariance measure produced with strategy 8 is almost four times smaller than that under strategy 1. While it can potentially be asserted that much of the performance of strategy 8 is generated by improvements in the mean level of *Milk Revenue* (e.g., highest mean and CE rankings), the VaR and semivariance rankings do corroborate the downside risk-reducing potential of this strategy.

The contrast between the performance of strategies 6 and 7 and strategy 8 is likely due to the option premiums paid by the members when using strategies 6 and 7. Minimum price contracts (strategies 11 and 12) also performed well in providing downside risk reduction relative to the cash-only strategy, with strategies 11 and 12 ranking second and third, respectively, for VaR, and third and fourth under the semivariance criterion.

Still, when considering all of the criteria, the performance of strategies 13 and 14 should be noted. These strategies rank third in terms of standard deviation following strategies 6 and 7. Given the liquidity constraints with options on Class III milk futures, the realistic implementation of strategies 6 and 7 as simulated in this study would be difficult. Given this, strategies 13 and 14 rank high, yet also better mimic reality. Across each criterion, strategies 13 and 14 provide considerable improvements relative to the cash-only strategy. In particular, the semivariance measure of $2.8 million produced by both strategies 13 and 14 is about half of that produced under the cash-only strategy.

Overall, these results corroborate those for *Local Savings*. That is, there is benefit to cooperative members in terms of the cooperative engaging in active risk management and offering risk management solutions to its members. However, a final assessment is warranted, based on how these risk management strategies impact total *Member Profits*, which considers both milk revenue and cooperative profits that eventually get transferred back to the members.

Member Profits

Table 5 provides the rankings of the strategies when considering total *Member Profits*. As defined in equations (1) and (10), *Member Profits* is a function of *Milk Revenue* as well as *Local Savings* that are distributed back to members in the form of patronage refunds and equity redemptions.

The benchmark strategy, strategy 1, ranks fifth in terms of standard deviation at $57.5 million, ninth in terms of coefficient of variation at 0.5191, VaR ($19.8 million), and semivariance ($4.4 million), and eleventh in terms of certainty equivalent ($109.7 million). Indeed, several of the strategies simulated provide improvement in the distribution of *Member Profits* relative to the cash-only benchmark.

In terms of risk reduction based on standard deviation, strategy 3, ranked first with a standard deviation of $10.3 million, provides a considerable decrease in

Table 5. Rankings of Alternative Risk Management Strategies: Member Profits

Strategy Number	Rank	Mean ($)	Rank	Standard Deviation ($)	Rank	CV	Rank	VaR ($)	Rank	CE ($)	Rank	Semi-variance[a] ($)
1	11	110,776,442	5	57,506,212	9	0.5191	9	19,766,569	11	109,676,074	9	4,372,186
2	9	111,807,919	6	58,436,818	10	0.5227	10	17,790,217	8	110,671,893	10	4,639,686
3	13	110,329,789	1	10,314,101	1	0.0935	1	93,740,782	9	110,294,349	1	0
4	12	110,671,633	8	64,804,378	11	0.5856	11	7,577,241	12	109,274,867	11	6,927,169
5	4	145,756,328	11	69,253,906	8	0.4751	7	35,989,236	4	144,163,299	8	3,313,302
6	1	194,547,384	9	66,873,795	4	0.3437	2	88,771,828	1	193,061,121	2	524,289
7	14	90,046,352	12	74,240,353	13	0.8245	12	-24,963,697	14	88,216,574	12	14,668,445
8	2	182,761,649	7	62,391,731	2	0.3414	3	84,009,361	2	181,467,617	4	930,812
9	8	112,133,987	13	95,169,360	14	0.8487	14	-45,902,606	13	109,119,447	14	21,929,525
10	10	110,794,735	3	48,864,367	6	0.4410	8	32,827,952	10	109,999,975	5	2,141,773
11	7	118,448,847	14	96,214,557	12	0.8123	13	-39,749,462	7	115,366,280	13	20,848,053
12	3	152,991,529	10	68,309,478	7	0.4465	5	44,395,352	3	151,441,402	7	2,588,686
13	6	128,772,744	4	56,208,260	5	0.4365	6	38,198,344	6	127,720,930	6	2,433,803
14	5	128,918,950	2	44,271,029	3	0.3434	4	58,491,304	5	128,266,318	3	668,153

[a] The threshold level, *T*, of *Member Profits* used in calculating semivariance [equation (6)] is $5,113,641. This number reflects the *Milk Revenue* threshold level as described in the footnote to Table 4, plus patronage refunds and the present value of equity redemptions derived from *Local Savings* described in the footnote to Table 3, less variable costs of production. Semivarance reported in the table is the square root of the semivariance measure defined in equation (6). The square root was taken to express the semivariance in dollar units.

standard deviation relative to both the benchmark strategy and other competing strategies. While this result is initially surprising, considering it did not perform among the best strategies when focusing strictly on *Local Savings* or *Milk Revenue*, it did perform well in reducing the total variability of *Member Profits* in (10). Although this strategy appears to perform well, the reality of the cooperative developing swap arrangements at advantageous prices for its entire cheese output is restrictive to its practical implementation.

Based on standard deviation, strategy 14 comes in a close second at $44.3 million. This combination strategy suggests that the total risk of member profit can be reduced relative to a cash-only strategy if the cooperative takes actions to manage risks of cheese prices through the execution of cash market transactions, forward contracting arrangements, and swaps, and simultaneously provides opportunities for members to engage in a variety of risk management strategies for their milk price. Strategy 10, also a forward contract offered to members based on the average price of prevailing futures markets prices, ranked third under the standard deviation criterion at $48.9 million.

Strategy 13, which does not incorporate the management of cheese price volatility by the cooperative, ranks fourth based strictly on standard deviation. The improvement in standard deviation of strategy 14 relative to strategy 13 is considerable ($44.3 million vs. $56.2 million). This improvement is also seen in the other evaluation criteria, namely in the downside risk measures of VaR and semivariance. The VaR of strategy 14 is $58.5 million (ranked fourth), while for strategy 13 it is $38.2 million (ranked sixth). So, there is a 5% chance that cooperative member profits will fall below $58.5 million under strategy 14, but a 5% chance that they will fall below $38.2 million under strategy 13. Corroborating these results, the semivariance for strategy 14 is $688,153, in contrast to $2.4 million under strategy 13. Only strategies 3 and 6 provide smaller semivariance measures, but both of these strategies maintain real constraints to their full implementation—namely, the ability to swap all the cheese volume or obtain the necessary options market liquidity. Indeed, the results for strategies 13 and 14 provide initial evidence that cooperative members' bottom lines can benefit from the cooperative taking a role in actively managing price risks of both cheese and milk.

The overall performance of strategy 8, one of the components of strategies 13 and 14, should also be highlighted. This is one of the most simplistic strategies offered by the cooperative—the ability of members to accept a forward price. While individual members' farms are likely to possess heterogeneous cost structures, the overall performance of this strategy suggests members who understand their costs and take advantage of opportunities to manage the variability of their milk price can improve the distribution of *Member Profits*.

The results associated with strategies 12, 10, and 6, which also involve the offering of forward contracts of some type by the cooperative, help confirm that there is indeed value in the cooperative offering risk management choices to members. Although trading costs are not considered in the simulation (e.g., brokerage costs and margin requirements), the cooperative is likely to be in a better position financially to bear at least the margin requirements necessary to make the forward contracts feasible. While brokerage fees could eventually be passed on to the members, liquidity constraints and lack of knowledge regarding hedging and derivatives products in general are likely to be a bigger obstacle for individual members in managing their milk revenue risks on their own using Class III milk futures and options. Our results confirm that the offering of risk management instruments to members in the form of forward contracts (various types) to manage the variability of their milk revenue, as well as the cooperative taking a lead in managing the variability of cheese revenues through a combination of swaps and forward contracts coupled with cash marketing, can improve the distribution of overall cooperative *Member Profits*.

Summary, Conclusions, Implications, and Potential Beneficiaries

Each year, agricultural cooperatives are responsible for producing and selling billions of dollars of farm output (Kraenzle, 1996). However, many cooperatives have not embraced active risk management practices at the same pace as their investor-owned competitors, but more routinely take a position of risk accommodation through the holding of capital reserves. While this is not a surprising action for investor-owned firms given the risk management irrelevance proposition (RMIP), the member-owner structure and other characteristics of agricultural cooperatives soften many of the rigid assumptions of the RMIP.

In particular, because the member-owner structure of cooperatives prevents most co-ops from issuing publically traded stocks, many risks to which cooperatives are exposed are "nontradable." Moreover, as cooperatives seek to preserve and increase membership in the face of competition from investor-owned firms, cooperatives may find it necessary to provide risk management services to their members as a point of differentiation and value added. Accordingly, cooperatives and their members are likely to benefit from active risk management.

In this research, we attempt to improve the understanding of how alternative risk management strategies—both those implemented by the cooperative as well as offered to its members—influence cooperatives' and cooperative members' bottom lines. Using Monte Carlo simulation methods, we specifically examine how various risk management strategies affect the distribution of *Local Savings*, member *Milk Revenue*, and *Member Profits* for a representative dairy cooperative which markets more than 1 billion pounds of milk per year. The specific risk management strategies examined are ranked using a variety of evaluation metrics, including metrics that focus on mean returns, traditional mean-variance efficiency (coefficient of variation), downside risk (VaR and semivariance), and utility maximization (certainty equivalent).

Overall, the results suggest that well-designed risk management strategies can benefit the cooperative as a business entity, and subsequently cooperative members alike. In the case of the representative dairy cooperative examined, particular benefits are offered to members by the cooperative providing forward contracts of various types on milk price in conjunction with the cooperative actively managing the variability of cheese prices through a combination of forward contracts, swap arrangements, and cash marketing.

The results also suggest that routine risk management strategies may not be optimal, and that various risk management strategies, combined with cash marketing of both milk and cheese, provide for improved risk reduction both in terms of total risk and downside risk at all levels examined. Granted, this result also presupposes considerable market knowledge and business acumen on the part of cooperative management and the cooperative member in the actual execution of such strategies (e.g., market timing ability). Still, the results indicate that a course of active risk management by the cooperative in terms of managing cheese prices, coupled with the offering of risk management tools to its members, can be beneficial to both the cooperative as a business unit and the cooperative member.

While the results point to considerable benefits of active risk management, some important caveats that may potentially impede the successful implementation of the simulated strategies should be noted.

The forward-contracting arrangements offered to cooperative members simulated here rely on the use of Class III milk futures and options. Indeed, while the volume of trade in these contracts has been growing since their inception, the overall lack of liquidity in these markets, in particular in the Class III milk options market, may make the practical application of many of the simulated strategies untenable. In addition, over-the-counter strategies such as swaps are subject to counterparty risks which may also pose an obstacle. Interestingly, the results of this research may point to the latent demand for these instruments in the dairy markets, which could ultimately foster greater liquidity in the milk futures and options markets themselves.

Despite these potential bottlenecks, the offering of risk management contracts to cooperative members, coupled with the active risk management of output prices by the cooperative, tends to benefit both the cooperative business and its members' financial performance. The results presented in this research provide a menu of suggestions as to how dairy cooperatives can implement alternative risk management approaches. Specifically, the cooperative can offer risk management tools to its members without worsening the cooperative's financial performance at the very least, and can potentially improve the risk/return profile of both the cooperative and subsequently member profits.

Moreover, cooperative members, managers, firms which provide inputs and services to cooperatives, and downstream customers of cooperatives such as processors, retailers, or exporters benefit from a better understanding of risk management practices and their impact on cooperative financial performance. For example, at the cooperative level, effective risk management may not only help improve the stability of cooperative members' income stream, but can also represent a critical source of savings. For instance, if a VaR analysis suggests a far lower capital reserve would be adequate to absorb a loss that can be expected to occur only 5% of the time, a cooperative could reallocate these resources to projects providing returns equal to, or greater than, their internal required rate of return.

Similarly, if reserve capital is being drawn from external sources, these funds can be redirected to more productive ends. Of course, it is always an option to use this increase in financial flexibility to return more capital to cooperative members. Either way, members should be better off as a result of their managers' more rigorous capital controls. More generally, greater financial transparency can only improve member commitment as members can be more confident that managers are taking a proactive approach to protecting cooperative equity.

Financial stability will, in turn, reduce the cost of both equity and debt capital to cooperatives. Members will require less return for leaving their equity exposed to market risk within the cooperative if that risk is appropriately controlled. Further, bankers will lend at a lower rate the lower a cooperative's probability of bankruptcy. Bankers are not the only group finding cooperatives with stable earnings more attractive investments. In fact, as shown by Richards and Manfredo (2003), cooperatives that are better capitalized are more likely to be involved in some form of acquisition or merger. To the extent that member-owners achieve synergies through consolidation, they will benefit from higher earnings in the future, whether these synergies emerge in top- or bottom-line performance.

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Evaluating the Effects of Asymmetric Information in a Model of Crop Insurance

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Abstract

Asymmetric information in the form of moral hazard and adverse selection can result in sizable program costs for government-provided crop insurance plans. We present a methodology and illustrative simulations to show how these two types of information problems interact in a way to create program costs for the providers of crop insurance. Our methodology allows us to ascertain the relative contributions to program costs of these two sources of asymmetric information. The exercise is useful in pointing out directions for future study seeking ways to improve the design of crop insurance plans.

Key words: adverse selection, crop insurance, moral hazard

There has been substantial empirical research into the effects of crop insurance on producer decisions regarding input use and program participation. Of particular concern have been the implications of insurance on the phenomena of moral hazard and adverse selection. This literature is very nicely reviewed in a paper by Knight and Coble (1997) with a particular focus on the Multiple Peril Crop Insurance (MPCI) program established by the 1980 Federal Crop Insurance Act. Based on their literature survey, findings of empirical studies have shown that this insurance program has generated substantial moral hazard and adverse selection effects, but the size or importance of these effects has not been well studied.[1]

In this paper we use a model and supporting simulations to illustrate a methodology for analyzing a publicly provided crop insurance program in the presence of both moral hazard and adverse selection. This is a valuable exercise because the implications on program costs and productive efficiency are affected quite differently by each of these phenomena. Either moral hazard or adverse selection complications may on their own create substantial and undesirable program costs for a public insurance program. However,

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[1] "Moral hazard and adverse selection effects [*combined* (our addition)] have been less extensively examined. Evidence of both has apparently been found whenever sought: however, only a few studies provide estimates of the magnitude of moral hazard and adverse selection effects on MPCI indemnities. . ." (Knight and Coble, 1997). See also Babcock, Hart, and Hayes (2004); Glauber (2004); and Rejesus et al. (2006).

identifying the extent to which these costs are generated by moral hazard or adverse selection is important.

Different policies and various approaches to information acquisition are necessary in attempting to ameliorate these two problems. For example, Turvey, Hoy, and Islam (2002) illustrate how even the threat of monitoring or audit, with a denial of indemnity if less than some reference input use is found, may be sufficient to discourage moral hazard. Lessons learned from the empirical work examining public crop insurance plans, in conjunction with models such as ours which attempt to isolate moral hazard and adverse selection effects, should also provide valuable insights for other public insurance programs.

We demonstrate that the implications of the two phenomena of moral hazard and adverse selection, when they present themselves jointly, can be compounding in that they may create program costs which are super-additive. For example, the cost of providing insurance may be inflated (relative to a scenario where symmetric information prevails) by 30% when both moral hazard and adverse selection are present, but only by (say) 5% if just moral hazard is present or only by 8% if just adverse selection is present. This implies that efforts by the insurer to overcome either one of the information asymmetries involved (i.e., hidden type or hidden input) may provide benefits (e.g., 30% of program costs) which far exceed those that would be expected if these problems were to be considered in isolation (e.g., 5% or 8%). Thus, a "bonus" may be achieved in removing either one or the other of these information problems (i.e., hidden action—the source of moral hazard, or hidden type—the source of adverse selection) when both are simultaneously present and generate program costs in a super-additive fashion.

Another way to examine this issue is to consider the above hypothetical numerical example. Since, under super-additivity, it is only the combined effects of moral hazard and adverse selection that create substantial program costs (i.e., 30% versus 5% or 8% separately), which problem of asymmetry of information is resolved in order to improve efficiency or control program costs may not be critically important, as long as one of the issues is resolved. In such a scenario, the insurer may wish to resolve the information problem deemed less costly to correct. Although we do not perform any explicit efficiency analysis in this paper, the welfare implications of our approach are quite evident.

As noted by Knight and Coble (1997), there is substantial empirical work concerning the implications of crop insurance on producers' decisions, both in terms of their input choices and participation in the program. To a limited extent, we design our simulation model to reflect this work. In particular, close attention is paid to the functional form for the distribution of crop yields and the design of the insurance program. Since we are not attempting to reflect precise real-world experience for a particular crop, and production of different crops requires quite different specific parameter values, the model should be viewed as providing a general methodological framework rather than a specific example of a particular crop.

Our base case scenario is calibrated to reflect a plausible crop insurance scenario as gleaned from a number of empirical studies. However, we stress that such a simulation-based approach as ours simply demonstrates what is possible, and any application to a specific crop insurance plan must be supplemented with empirical work based on the specific crop/scenario being considered.

The most interesting result of our simulations is the demonstration of the possibility that the program costs from the combination of moral hazard and adverse selection problems may be super-additive. Specifically, the combination effect on overall program costs may be greater than the costs resulting from each information problem considered separately.

This means elimination or amelioration of either one of the two problems may have greater benefit than might be expected due to this interaction, should it exist in a specific case. We emphasize, however, that our simulation-based approach can only demonstrate this as a possibility. Consequently, any specific application of this suggestion to a particular crop insurance program would require empirical analysis at the level of the specific crop and scenario being considered.

Arnott (1992, p. 355) reports there is only a limited theoretical literature on the implications of hidden effort (moral hazard) and hidden type (adverse selection) both being present in an insurance market setting due to the complexity generated.[2] It is for this reason that we use a simulation-based approach.

The Basic Model

In this section the basic model is developed to describe the producer's optimal input choice for both cases in which insurance is and is not provided. We illustrate how this model is calibrated to generate our simulations, demonstrating how one can determine the relative impacts on program costs of adverse selection and moral hazard.[3] The simulation results and their discussion are presented in the following section. Although we choose our functional forms and parameters in order to reflect knowledge gained from some of the previous empirical studies that have analyzed the impact of crop insurance on producer decisions, we keep the model as simple as possible to demonstrate transparently how to identify the relative contributions of moral hazard and adverse selection to program costs. Actual applications of our methodology would require case-specific adjustments to our choice of parameters and other modeling assumptions.

We assume output, $\tilde{y}$, is a random variable which depends on a single input chosen, x, the state of nature, ω, and an agent type-specific parameter, ϕ. Higher-productivity producers will be associated with a higher value of ϕ, which, for example, could reflect higher quality land. The state of nature, ω, which reflects weather and other growing conditions, will be modeled whereby higher values represent better growing conditions, and hence higher output. A higher input value, x, is assumed to generate higher output in any given state of nature. We describe the production process according to a production function:

(1) $\tilde{y} = f(x, \omega, \phi)$,

with $f_x > 0$, $f_{xx} \leq 0$, $f_\omega > 0$, and $f_\phi > 0$.[4] For the purpose of our simulations, the following specific production function is adopted:

(2) $\tilde{y} = x^\lambda \omega \phi$,

where $\lambda \leq 1$. Thus, production is multiplicative in both the random variable ω and the agent type-specific parameter ϕ. The distribution function for output, conditional on a given x and ϕ, will be inherited from the distribution function assumed for ω. In our simulations, the beta distribution function is used for ω because of its flexibility.

We assume only one input in order to maintain simplicity in this part of the model and, as noted earlier, to promote transparency regarding the relative effects of adverse selection and moral hazard on

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[2] For some examples, see Picard (1987), Hoy (1989), and the few other references given in Arnott (1992).

[3] Comparative static results indicating the effect of changes in various parameters (e.g., output price) on input use have been developed by Leathers and Quiggin (1991), Ramaswami (1993), and others using theoretical models of insurance. Our simulation model is designed explicitly to demonstrate how to measure the size of program costs due to the two problems of moral hazard and adverse selection rather than comparative static effects per se.

[4] This production function is similar to the one used by Quiggin, Karagiannis, and Stanton (1993). Any constant term can be included within the definition of ϕ, as well as the level of any fixed inputs.

input decisions of producers and program costs for the providers of insurance. While it would be interesting to allow for a set of inputs, some of which would increase and others which would decrease the riskiness of the production process,[5] we leave such variations to potential future work.

In the absence of insurance, the producer chooses the input level x to maximize expected utility of profit. Let p be the price of the product[6] and w the per unit input cost. A fixed cost could be included without loss of generality. Thus, profit with no insurance for a producer of type ϕ is written as:

$$(3)\quad \pi(x, \omega, \phi) = pf(x, \omega, \phi) - wx.$$

The producer chooses input x to maximize expected utility of profit. Letting $u(\pi)$ be the elementary von Neumann-Morgenstern utility, $g(\omega)$ be the probability density function for the random variable ω, and ω_L and ω_U the respective lower and upper limits for ω, the producer's optimization problem becomes:

$$(4)\quad \underset{\{x\}}{\text{Max}}\, EU_n(x) = \int_{\omega_L}^{\omega_U} \left[u\left(pf(x, \omega, \phi) - \omega x\right)\right] g(\omega)\, d\omega,$$

where EU_n denotes expected utility with no insurance.

We now model how the insurance program is designed and determine the relevant optimization problem for a producer conditional on purchasing insurance. A critical yield is determined by the insurer, denoted as y_c, and any shortfall below this level determines the indemnity or payout $p(y_c - y)$ if actual output $y < y_c$. Since output depends on the input chosen (x) and the type-specific productivity parameter (ϕ), as well as the random variable (ω), it follows that conditional on any pair (x, ϕ) and critical level y_c, there is some critical value of ω (ω_c) which triggers an insurance payment (i.e., $y < y_c$ whenever $\omega < \omega_c$). Thus, we can write ω_c as a function of x, ϕ, and y_c [i.e., $\omega_c(x, \phi, y_c)$]. The probability that an indemnity is received is given by:

$$(5)\quad k(x, \phi, y_c) = \int_{\omega_L}^{\omega_c(x,\phi,y_c)} g(\omega)\, d\omega.$$

We assume, consistent with equation (2), that $k_x < 0$, $k_\phi < 0$, and $k_{y_c} > 0$. Letting ρ denote the cost of the insurance policy to the producer, the profit function for a producer who purchases insurance is represented by:

$$(6)\quad \pi(x, \omega, \phi) = \begin{cases} py_c - wx - \rho & \text{if } y < y_c, \\ pf(x, \omega, \phi) - wx - \rho & \text{if } y \geq y_c. \end{cases}$$

The producer's decision problem conditional on purchasing insurance is expressed as:

$$(7)\quad \underset{\{x\}}{\text{Max}}\, EU_w(x) = k(x, \phi, y_c)\, u(py_c - wx - \rho) + \int_{\omega_c(x,\phi,y_c)}^{\omega_U} \left[u\left(pf(x, \omega, \phi) - \omega x - \rho\right)\right] g(\omega)\, d\omega,$$

where EU_w denotes expected utility with insurance. The first term on the right-hand side of equation (7) represents the utility conditional on an insurance payout being triggered multiplied by the probability that an insurance payment is in fact triggered. Conditional on a payout being triggered, input use has negative value to the producer (i.e., it incurs costs without generating revenue).

Moreover, given our assumptions, increasing input x leads to a lower probability of being in a payout state. In this sense, the first term of equation (7) illustrates in part how insurance reduces

[5] The way we model production implies that an increase in the single input x leads to greater riskiness in production as well as higher expected output. In a multiple input model it is quite plausible, for example, that some inputs could both increase expected yield and reduce riskiness.

[6] For simplicity, we assume price is not random. The possibility of hedging allows producers to treat the futures or forward price as a certain price in making production decisions (see Holthausen, 1979). Especially if a crop insurance plan allows the futures price to be the basis of repayment, as does the Ontario Crop Insurance plan, then treating price as nonrandom is a reasonable assumption.

the value of the input to the producer and so creates a moral hazard effect. A larger trigger value, y_c, ceteris paribus, increases the likelihood of being in a payout state. By the way we model different productivity types, we also assume, ceteris paribus, a low-productivity type is more likely to be in a payout state of the world (i.e., $k_\phi < 0$). In all of our simulations, the lower-productivity types do indeed choose a lower optimal value of x. A higher trigger value (coverage level) leads to a lower input level as well.

Nevertheless, the implications of changing parameter values such as y_c and ϕ on the optimal choice of input x are less clear-cut in general terms than the above paragraph suggests. The optimal choice of input must take into account the effects of the input level on utility in both payout and non-payout states [the first and second terms of equation (7), respectively] as well as the effect of the input choice on the relative probabilities of those two sets of states. In a general context, therefore, the impact of changes to these parameters on the optimal values of input x are not unambiguous. Moreover, a change in the coverage level y_c would induce a change in the actuarially fair price of the policy, ρ. However, we have in mind a model in which the insurance buyer is offered a single policy described by the pair of parameters (y_c, ρ) and we do not consider the possibility of the insured selecting from a set of policies each with a different coverage level and corresponding price.[7]

Further, we treat the decision problem in general as one made in the short run. Therefore, although the level of price of the output affects both the optimal input level and the cost of insurance, we assume output price is fixed (as noted earlier) at the time the insurance policy is purchased and the input decision is made. Thus, from year to year, one would expect the price of insurance to change both directly because of the rate at which indemnities are satisfied, and because of the effect of price on input level chosen.[8]

Three alternative scenarios are considered for the insurance scheme based on the information possessed by the insurer concerning the input levels of the producers and their productivity types. In all cases, the insurer is assumed to choose a coverage level that is some fraction of the average yields for producers who do not purchase insurance, which in effect represents outcomes in the absence of insurance. The insurer determines a price of insurance covering the actuarial or expected cost of indemnities based on yields generated in the absence of insurance provision. Because the purchase of insurance leads to changes in behavior, the actual expected costs of providing insurance will generally differ from the computed values. This is, of course, the crux of the problem with publicly provided insurance plans, and it is the difference in these costs—which we denote program costs—that is the focus of our attention.

In the first scenario modeled, we assume the insurer can observe the productivity type of each producer, ϕ, and bases the price of insurance on that information. Thus, high- and low-productivity types pay different prices for insurance, and the probability of an insurance payment being triggered also depends on the producer's type. This scenario is referred to as "moral hazard only."

We then consider the operation of the insurance plan on the basis of inputs x being observed but productivity type ϕ not

[7] This would be an interesting avenue of research to explore as it may allow the insurer greater ability to screen insureds according to productivity types in the manner of the Rothschild-Stiglitz (1976) model.

[8] Although assuming a nonrandom price is justified by price risk being hedged for the component of output that is insured, this is not so clear-cut for the part of output that is sold conditional on being in a non-payout state of the world. Within the non-payout states, the amount of output that should be hedged is random, and so the amount to hedge is a more complex decision. However, to depart from this simplification would complicate the model unnecessarily.

observed by the insurer. This scenario is identified as an environment of "adverse selection only." Here, the insurer is presumed to know the appropriate input levels that would be chosen by each productivity type, were this observable, but the insurer is unable to determine in the case of an individual farmer his or her specific productivity type.

In the final scenario investigated, the insurer can observe neither the input level chosen by producers nor their productivity types. The coverage level for insurance and its price is based on the pooled experience of the various productivity types in the absence of insurance. The insurer cannot determine the type of the producers who do buy insurance and also cannot observe their input levels. Accordingly, we refer to this scenario as one of "moral hazard and adverse selection."

In our simulations we compare the program costs, which are defined as the difference between expected insurance payouts and premium revenue collected for each scenario. In this way we can observe the relative importance of moral hazard and adverse selection in generating these costs. Alternatively, the premium levels could be adjusted upward in order to offset these costs, either fully or partially, and so our calculations also indicate the extent to which this would be required. Of course, increasing the costs of the insurance premiums could affect the selection of insureds, with higher-productivity types more likely to view insurance as unattractive, thereby exacerbating the impact of adverse selection, and possibly leading to even more losses for the insurance plan.

Description of the Simulation Model

In this section the basic model is described, as well as associated assumptions for the simulations used to generate our results. First, we explain how our assumptions relate to the empirical literature on crop production and insurance. As noted in the introduction, our simulation model is designed to reflect these results, although we are not attempting to replicate any particular crop setting.

Profit from crop production is as specified in equation (3), with the production function $\tilde{y} = x^{\lambda}\omega\phi$ as given in equation (2). We use the parameter value $\lambda = 0.96$ for our base case and also adopt a range of values in our simulations.[9] A beta distribution function is used for our random variable ω in the base case, and a truncated normal is also adopted for the purpose of sensitivity analysis. The particular beta distribution adopted is the one with parameter values $\alpha = 2.5$ and $\beta = 2$, which determines the density function as expressed in equation (8) and illustrated in Figure 1:

$$(8) \quad g(\omega) = \frac{\omega^{\alpha-1}(1-\omega)^{\beta-1}}{\int_{\omega_L}^{\omega_U} t^{\alpha-1}(1-t)^{\beta-1}\,dt}.$$

What is most important in choosing our parameters and functional forms is the shape of the distribution function for the random variable ω and the resulting distribution of y which is inherited from it. This is important because the shape of the distribution function, in conjunction with the coverage level y_c, determines in relative terms: (*a*) all of the parameters of the insurance program, (*b*) the incentive to purchase insurance, and (*c*) the optimal input level conditional on insurance being purchased.[10]

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[9] Quiggin, Karagiannis, and Stanton (1993) find, for a heterogeneous collection of grain farmers, the null hypothesis of constant returns to scale cannot be rejected.

[10] The beta distribution and normal distribution have been used extensively in the empirical literature. See Babcock and Hennessy (1996) for an example of use of the beta distribution, and Just and Weninger (1999) for an example of the use of the normal distribution. Ker and Coble (2003) provide a comprehensive review and critique of the empirical methods used to choose between these two distributional approaches. Nonparametric methods have also been employed (e.g., Ker and Goodwin, 2000).

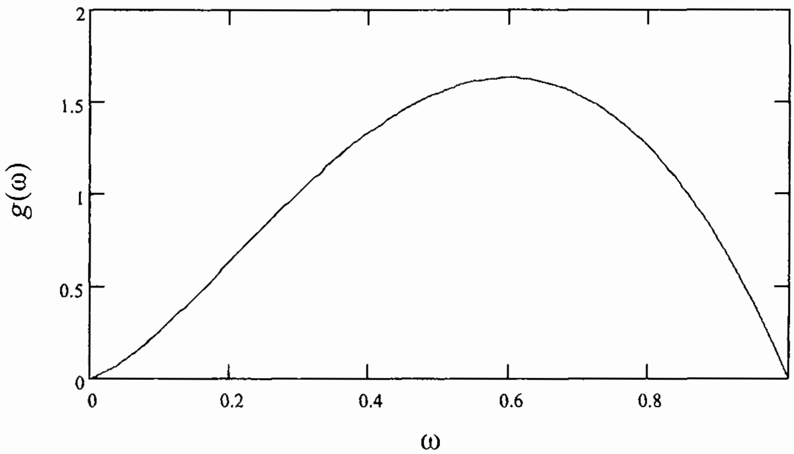

Figure 1. Beta Distribution with Parameters α = 2.5 and β = 2

Note that the production function is multiplicative in ω, and so the input is risk increasing (i.e., an increase in x leads to an increase in the variance of crop yields). The literature on crop insurance has addressed the question of the impact of insurance on input use for cases of multiple inputs, with some being risk increasing and others risk reducing. Use of a multiple input model with both types of inputs would increase the complexity of our model beyond what is required to demonstrate the basic issues we are analyzing. Nonetheless, since the impact of insurance on input use may well be qualitatively different for these different types of inputs, this is an interesting topic for future work.[11]

In our base model, risk preferences are assumed to be summarized by the exponential utility function, $U(\pi) = -e^{\gamma\pi}$, where π is profit from producing the crop. This utility function implies constant absolute risk aversion of degree γ. We adopt a range of values of γ in our simulations. A substantial literature has emerged which attempts to measure the risk preferences of individuals.[12] The most popular functional forms used in empirical estimation of $U(\cdot)$ have been those representing constant absolute and constant relative risk-aversion preferences.

Empirical estimates of the degree of risk aversion vary widely. As pointed out by Choi and Menezes (1992), for those studies employing a constant relative risk-aversion utility function, the range of the degree of risk aversion has been from 0.05 to more than 1,000. Some empirical research has attempted to identify which functional form—constant absolute risk aversion or constant relative risk aversion or neither—is most appropriate. Saha (1993) proposed a flexible form of utility function which allows for a combination of properties associated with absolute and relative risk aversion. There have also been a number of studies focusing on risk preferences specifically for farmers (see references in Saha, 1993). These investigations have also reported a wide range of results. Consequently, there is no obvious choice for a specific functional form to model risk preferences, let alone a specific parameter value which accurately reflects the degree of risk aversion.

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[11] See, for example, Quiggin, Karagiannis, and Stanton (1993) who note, "Pesticides are generally viewed as a risk-reducing input and fertilizer as a risk-increasing input" (p. 103). For their study, however, they go on to state that "testing revealed no significant loss in power from aggregating the two inputs" (p. 103).

[12] See, for example, Blake (1996), who refers to much of this literature.

This problem is exacerbated in our model since we are considering only one aspect (i.e., decisions with respect to a single crop) of a producer's portfolio of assets and production streams.[13] Of particular relevance to our choice is the recent paper of Guiso and Paiela (2006) measuring the parameter of absolute risk aversion from revealed preferences over a hypothetical lottery question. The authors observed a wide range of values within the population surveyed, with the 10th percentile having a degree of absolute risk aversion equal to 0.08 while the 90th percentile had a value of 0.20 (i.e., ranked from least to most risk averse). Given the above discussion, we choose a variety of parameter values in our simulations, with the constant absolute risk-aversion utility function with degree $\gamma = 0.10$ for our base case.

Simulation Results

In this section our main simulation results are presented. As noted above, the specific parameter values used in our base case were based broadly on empirical studies of crop production and insurance. In particular, the base case parameter assumptions and outcomes are consistent with the empirical estimation of Babcock and Hennessy (1996) for corn production from a group of Iowa farms. As in their model, we adopt a scale assumption reflecting a single acre of corn.[14] Likewise, we select the same output price of $p = 2.2$. Our base case has yields distributed according to the beta distribution, which is the same functional form used by Babcock and Hennessy.

One major difference in our analysis, however, is our use of a single input, x, intended to reflect an index of various inputs. Thus our input price (w) has no meaning per se in terms of any specific input. We calibrate it at $w = 0.075$ to generate similar results to the Babcock and Hennessy (1996) model, which in our base case leads to the plausible result of expected output of 138 bushels of corn per acre for the high-productivity type producer (in the absence of insurance).

In our simulations, we find it is often optimal for producers to choose a zero input level (corner solution) when offered insurance. This extreme outcome is the result of being guaranteed a decent revenue from insurance even if zero input is used. Yet, this is actually just an artifact of the model, since in the real world the insurer can directly observe at least some minimal input usage.[15] We assume this is indeed possible, but at a rather modest level of fraction $t = 0.25$ of normal or best-practice input use being observable to the insurer.[16] Given this amount, results reveal that an interior optimum occurs with an input level substantially more than 25% of the input level used when no insurance is available, as depicted by the graph in Figure 2. The higher the level of insurance coverage, however, the more tempting it is for insureds to adopt the extreme moral hazard decision (i.e., $x = 0$).

Returning to our base case simulation, the other parameter values chosen are: (*a*) $\phi_h = 1$, $\phi_l = 0.8$, which reflect the differences in productivity of the high- and low-productivity types;[17] (*b*) a coverage level for insurance of $r = 0.5$, which implies a trigger or guaranteed minimum revenue reflecting a production level of 50% of

[13] Because our objective function reflects an attitude toward risk for a given crop decision, the parameter value chosen may not reflect at all the overall risk preferences of the producer. Bar-Shira, Just, and Zilberman (1997), for example, found that the degree of risk aversion varied across crops and other aspects of farmers' decisions.

[14] See Babcock and Hennessy (1996) for detailed explanations of these assumptions.

[15] The need for and implications of a minimal input requirement are investigated in detail in another paper (Turvey, Hoy, and Islam, 2002).

[16] In scenarios when producer type is not observable, we adopt the more conservative assumption that the fraction t applies to the input level chosen by low-productivity types.

[17] Note that we restrict differences in productivity type to be reflected in a multiplicative manner in the production function. One could, of course, adopt alternative approaches.

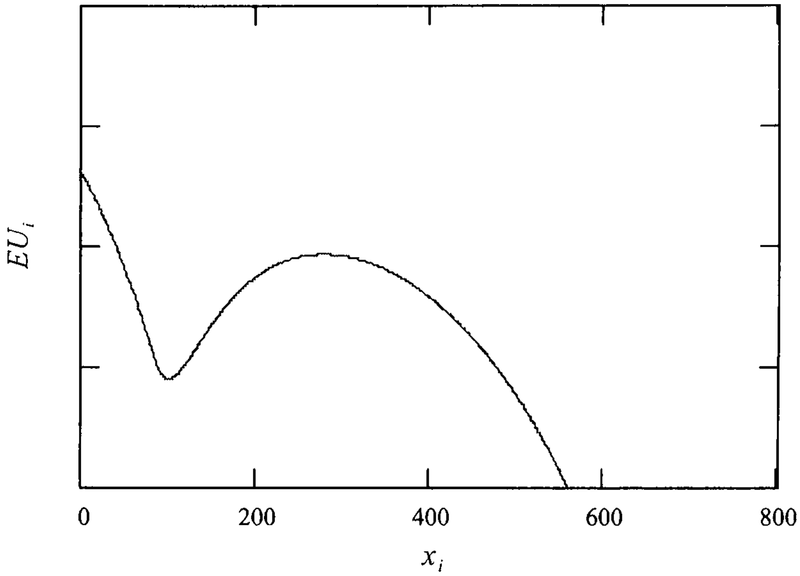

Figure 2. Expected Utility-Maximizing Choice of Input

average yields achieved in the absence of insurance; (*c*) $\lambda = 0.96$ (base case production function parameter, as described earlier); and (*d*) $\alpha = 2.5$, $\beta = 2$ (parameters of the beta distribution).

The insurance coverage level in the base case is quite low in comparison to real-world coverage levels. However, we wanted to start with such a low value to illustrate what occurs as this value is increased. In particular, at coverage level $r = 0.5$, a minimal input requirement of $t = 0.25$ is sufficient to guarantee interior optima in all scenarios. As the level of insurance coverage rises, the minimal input requirement must increase to ensure an interior optimum in all cases. For all subsequent simulations, we use $t = 0.5$ as our minimal input requirement, and indicate in which cases this is confirmed to be binding. The results of our base case and variations are provided in the first row of values reported in each of Tables 1–3.

In what follows, when a calculation refers to a high-productivity producer type, subscript *h* is used, and subscript *l* is used when referring to a low-productivity type. In our base case and when only moral hazard is present (Table 1), the two producer types (low and high) receive insurance contracts based on the past experience of producers of their own type when insurance coverage is not in force. With no insurance, the optimal input levels are $x_h = 313$ and $x_l = 310$, with corresponding expected output levels of $Ey_h = 138$ and $Ey_l = 110$ for high- and low-productivity types, respectively. The trigger value (or coverage level) for the two types is 50% of their risk type-specific expected yields (i.e., $y_{ch} = 69$ and $y_{cl} = 55$). Using these trigger values and the type-specific yield distributions which apply under the no-insurance scenario, the expected indemnities, and hence premiums, are $\rho_h = 5.23$ and $\rho_l = 4.15$.

With these insurance policies in place, the producers reduce their input use to $x_h = 280$ and $x_l = 279$ (Table 1). With these reduced input levels, expected output levels fall to $Ey_h = 124$ and $Ey_l = 99$ and the average indemnities, at $EI_h = 6.7$ and $EI_l = 5.25$, are actually higher than the premiums charged, which were based on yields of producers who did not purchase insurance. The result is that claims exceed revenues collected by the amounts of 26.6% for low-productivity types and 28% for high-productivity types.

Table 1. Base Case and Sensitivity Analysis: Moral Hazard Only

Change to Base Case	No Insurance				Moral Hazard Only							
	Input		Expected Output		Input		Expected Output		Probability of Claims		Program Costs (%)	
	x_l	x_h	Ey_l	Ey_h	x_l	x_h	Ey_l	Ey_h	k_l	k_h	c_l	c_h
Base	310	313	110	138	279	280	99	124	0.14	0.14	27	28
$\lambda = 1$	326	327	145	182	291	292	129	162	0.15	0.15	30	30
$\lambda = 0.8$	244	250	36	46	220	226	33	42	0.14	0.14	21	21
$\beta = 3$	304	307	88	111	250	252	73	92	0.20	0.20	51	51
$\beta = 1.5$	314	313	125	156	297	298	118	148	0.11	0.11	14	12
$\alpha = 2$	248	250	80	100	221	223	71	90	0.19	0.19	22	22
$\alpha = 3$	374	373	142	177	337	338	128	161	0.11	0.11	32	30
$\gamma = 0.05$	621	626	213	269	558	559	192	241	0.14	0.14	27	28
$\gamma = 0.15$	207	209	74	94	186	187	67	84	0.14	0.14	26	28

Parameters for Base Case:

- Distribution of Random Variable ω: $g(\omega) \sim \text{Beta}(\alpha, \beta)$, $\alpha = 2.5$, $\beta = 2$
- Prices of Input and Output: $p = 2.2$, $w = 0.75$
- Production Function and Risk-Aversion Parameters: $\lambda = 0.95$, $\phi_h = 1$, $\phi_l = 0.8$, $q_h = 0.5$, $q_l = 0.5$, $\gamma = 0.1$
- Insurance Policy Parameters:
  (*a*) Minimum Input Requirement: $t = 0.25$ ($t = 0.5$ for all other cases)
  (*b*) Coverage Level: $r = 0.5$ (i.e., 50%)

Tables 1–3 also report the probability of insurance being triggered (k_l and k_h).

Next, we model the implications of adverse selection only (Table 2). This scenario assumes the insurer can monitor and enforce any specific level of input desired, and so chooses the average input level adopted by the two types of producers in the absence of insurance. This being the case, major complications in terms of program costs arise from adverse selection only when high-productivity types drop out of the insurance market. In scenarios where high-productivity types do drop out, however, substantial program costs can be generated from the problem of adverse selection on its own. This is because the premium is computed on the basis of a group of farmers, including high-productivity types, and therefore can be far too low to cover the claims experience of a population of insureds comprised of only low-productivity types.

If the insurer is unable to identify which producer is of which type, the insurer's observations of production across producers in the absence of insurance reflect a mixed probability distribution of the two types. In our base simulation, it is assumed the population of producers is made up of 50% of each type. Consequently, expected output in the absence of insurance is the average expected output across types ($Ey_a = 0.05Ey_h + 0.5Ey_l = 124$), and so the trigger value of yield is $y_{ca} = 62$. The expected indemnity, and hence the premium charged using the mixed probability distribution, is $\rho_a = 4.92$.

Insurance is relatively more attractive to low-productivity types and less attractive to high-productivity types than when the types can be assessed contract terms (i.e., trigger values and premia) that are risk type-specific. In this example, the high-productivity types make a claim with probability $k_h = 0.09$, while the low-productivity types make a claim with probability $k_l = 0.15$ (Table 2) compared to $k_h = k_l = 0.14$ in the case when only the problem of moral hazard persists (Table 1).

Table 2. Base Case and Sensitivity Analysis: Adverse Selection Only

Change to Base Case	No Insurance			Adverse Selection Only				
	Input		Expected Output	Input	Expected Output	Probability of Claims		Program Costs (%)
	x_l	x_h	(average)	$x_l = x_h$	(average)	k_l	k_h	(overall)
Base	310	313	123.9	312.0	123.8	0.15	0.09	0.23
$\lambda = 1$	326	327	163.4	326.7	163.4	0.15	0.09	0.04
$\lambda = 0.8$	244	250	41.0	247.0	41.0	0.15	0.09	0.58
$\beta = 3$	304	307	99.5	305.5	99.4	0.17	0.11	0.24
$\beta = 1.5$	314	313	140.3	313.7	140.3	0.13	0.07	0.05
$\alpha = 2$	248	250	89.9	248.9	89.8	0.19	0.13	0.13
$\alpha = 3$	374	373	159.1	373.5	159.1	0.11	0.06	0.10
$\gamma = 0.05$	621	626	241.0	623.4	241.0	0.15	0.09	0.25
$\gamma = 0.15$	207	209	84.0	208.0	84.0	0.15	0.09	0.27

Parameters for Base Case:
- Distribution of Random Variable ω: $g(\omega)$ ~ Beta(α, β), $\alpha = 2.5$, $\beta = 2$
- Prices of Input and Output: $p = 2.2$, $w = 0.75$
- Production Function and Risk-Aversion Parameters: $\lambda = 0.95$, $\phi_h = 1$, $\phi_l = 0.8$, $q_h = 0.5$, $q_l = 0.5$, $\gamma = 0.1$
- Insurance Policy Parameters:
  (*a*) Minimum Input Requirement: $t = 0.25$ ($t = 0.5$ for all other cases)
  (*b*) Coverage Level: $r = 0.5$ (i.e., 50%)

Expected indemnities are $EI_h = 3.67$ and $EI_l = 6.16$. Since both types pay the same premium for insurance, the high-productivity types subsidize the low-productivity types—a common characteristic of adverse selection. Overall, the program costs are found to be negative; i.e., the average premium revenue exceeds the average claim, albeit by the insubstantial amount of 0.24 of a percentage point.[18]

Now consider the scenario in which both adverse selection and moral hazard are present (Table 3). Here, the insurer can observe neither an individual producer's input level beyond the minimal that can be required through direct monitoring (i.e., the minimum standard) nor the producer's productivity type. Unlike the case of observable input use but unobservable producer type, there is an incentive for each type to reduce input usage. This incentive is greater for the low-productivity types since they are more likely to be in a state of nature that triggers a claim, and in such circumstances the marginal benefit of input usage is zero.

Moreover, unlike the case where only moral hazard persists, the insurer cannot design the contracts specifically to exploit the different incentives for the two productivity types. In particular, the insurer is unable to set a lower trigger value for the low-productivity type, which was 55 bushels/acre under moral hazard only but is 62 bushels/acre in this scenario. The result is that low-productivity types reduce their input level to $x_l = 270$ compared to the level of 279 in the moral-hazard-only scenario. In contrast, high-productivity types face opposing incentives, as their trigger value falls from 69 to 62 when adverse selection is also present. Hence, they increase their input level from 280 to 285.

[18] Under adverse selection, the same input requirement is imposed on both types and so, relative to input choice with no insurance, where $x_h > x_l$, low-productivity types increase their input level while high-productivity types decrease their input level—although only a little in this case. Hence, the balance of these effects on program costs can be small. Such small program costs from adverse selection generally is not a result to be expected.

Table 3. Base Case and Sensitivity Analysis: Moral Hazard and Adverse Selection

Change to Base Case	No Insurance				Moral Hazard and Adverse Selection						
	Input		Expected Output		Input		Expected Output		Probability of Claims		Program Costs (%)
	x_l	x_h	Ey_l	Ey_h	x_l	x_h	Ey_l	Ey_h	k_l	k_h	(overall)
Base	310	313	110	138	270	285	96	126	0.20	0.11	31
$\lambda = 1$	326	327	145	182	283	297	126	165	0.20	0.11	33
$\lambda = 0.8$	244	250	36	46	212	230	32	43	0.19	0.10	25
$\beta = 3$	304	307	88	111	232	262	68	95	0.30	0.15	61
$\beta = 1.5$	314	313	125	156	293	301	117	150	0.15	0.08	14
$\alpha = 2$	248	250	80	100	215	227	69	91	0.25	0.15	14
$\alpha = 3$	374	373	142	177	327	344	124	164	0.16	0.07	36
$\gamma = 0.05$	621	626	213	269	541	571	187	246	0.20	0.11	31
$\gamma = 0.15$	207	209	74	94	181	191	65	86	0.20	0.11	30

Parameters for Base Case:

- Distribution of Random Variable ω: $g(\omega)$ ~ Beta(α, β), $\alpha = 2.5$, $\beta = 2$
- Prices of Input and Output: $p = 2.2$, $w = 0.75$
- Production Function and Risk-Aversion Parameters: $\lambda = 0.95$, $\phi_h = 1$, $\phi_l = 0.8$, $q_h = 0.5$, $q_l = 0.5$, $\gamma = 0.1$
- Insurance Policy Parameters:
  (*a*) Minimum Input Requirement: $t = 0.25$ ($t = 0.5$ for all other cases)
  (*b*) Coverage Level: $r = 0.5$ (i.e., 50%)

On balance, however, the program costs in this case are exacerbated by the presence of both information asymmetries.

The result in this example is that program costs for low-productivity types are 70% of premiums collected, while the high-productivity types subsidize the program in the amount of 9% of their premiums. Overall, the average insurance claims in this scenario represent 30.6% more than premiums collected—a higher percentage than the combined cases of moral hazard (26.6%) and adverse selection (-0.24%) taken independently. Thus, we obtain a super-additivity result regarding the effects of these information problems on program costs.[19]

To ensure robustness of the base case, we perform "sensitivity" analysis by changing the parameter values for the distribution function $g(\omega)$ (i.e., via changes in α and β), the value of the exponent of the production function (λ), and the risk-aversion coefficient (γ). Again, the results are reported in Tables 1–3. The changes often have predictable results. For example, increasing λ to 1 leads to increased input levels in all scenarios, while decreasing λ leads to reduced input levels, as would be expected. The effects of changes in the parameter values α and β on the distribution function $g(\omega)$ are illustrated in the five figure graphics in the appendix.

One case in particular deserves attention. Increasing β to 3 creates a substantially fatter left tail (appendix Figure A2).[20] Since a fatter left tail means the insured producer is more often in a situation of having output below the trigger value, this leads to a reduction in the expected marginal value of the input while increasing

[19] This super-additivity result would be expected to be even stronger if the insurance terms became unattractive to the higher-productivity types and they left the pool of insureds.

[20] Although the beta distribution affords substantial flexibility in representing different shaped distribution functions, as one obtains a higher variance the curve flattens and then becomes U-shaped, which is not generally a desirable property for representing a distribution of crop yields.

the advantage of insurance to the producer. In the moral-hazard-only scenario, the result is an increase in experiencing claims; consequently, the moral hazard effect is enhanced, as is the super-additivity property associated with the presence of both moral hazard and adverse selection problems.

Although not presented here, we also considered the impact of quantitatively larger changes to parameter values designed to generate more dramatic effects in the relative program costs of insurance in the various scenarios.[21] The results yielded two principal lessons with respect to what happens when increasing the coverage level, and when making the differences between the productivity types large (i.e., the ratio ϕ_h/ϕ_l). Increasing the coverage level enhances the incentive to engage in moral hazard and therefore, as expected, tends to increase program costs either in the scenario with moral hazard only or with both moral hazard and adverse selection problems persisting simultaneously. This is driven by the fact that the impact on the incentives of low-productivity types is especially pronounced in such cases. Using the base case parameter values but with a trigger value reflecting 70% coverage rather than 50% coverage, for example, we found the program costs to be 67% of premiums collected under moral hazard only and 185% with both moral hazard and adverse selection. This example displayed a very strong super-additivity property.

However, we stress that sub-additivity can also occur.[22] Using the same parameters as above but increasing the coverage rate to 80% leads to a situation in which both low- and high-productivity types reduce their input use under insurance to the minimally required amounts. When adverse selection is also present, the resulting trigger value of claims from the high-productivity type's perspective is so low (since it is essentially the average of that for low- and high-productivity types combined), the high-productivity types opt for a higher input use (i.e., an input choice representing an interior optimum). The result is that the program costs with both types of asymmetric information are substantially less than for the two types considered independently, revealing the possibility of sub-additivity of costs.[23] Moreover, increasing the difference in productivity types generates a stronger incentive for low-productivity types to engage in moral hazard when adverse selection is also present, thereby potentially generating a more pronounced super-additivity effect.

Conclusions

Our analysis is based on hypothetical simulations. Although we have chosen our parameters and functional forms in such a manner as to reflect what has been learned in the empirical research about behavior in risky environments in general and in a crop insurance context in particular, one must of course be very careful in drawing conclusions regarding the design of public crop insurance programs from any simulation study alone. Nonetheless, we believe we have learned a number of important lessons at least regarding what *could* occur in some scenarios involving information problems arising from hidden action (moral hazard) and hidden type (adverse selection).

Of particular interest from our results is the possibility of a super-additivity property. Specifically, it is possible that the sum of the program costs associated

[21] These additional results, along with more detailed analysis of all simulation results, appear in the working paper version of this study (www.economics.uoguelph.ca/econ/Research/DisPapers/2007_6.pdf).

[22] Stewart (1994) adopts a simulation-based approach to develop some insights via a model that adds moral hazard considerations to the classic Rothschild and Stiglitz (1976) model of adverse selection. He finds a sub-additivity result, although that work applies to a context very different from our problem.

[23] For the particular example highlighted, the program costs under moral hazard only are 264% of premiums collected, while with both information problems costs are only 174%.

with either type of information asymmetry considered separately may be less than the program costs arising from these problems when they occur together. This is because when moral hazard alone is a consideration, the terms for insurance can be specifically designed for each type of producer.

In particular, low-productivity types can be assigned a lower trigger value for the critical crop yield below which claims are made. If productivity type cannot be observed, then the trigger value by necessity will be based on average output of the pooled group of producers, and therefore may be so high as to induce a substantially higher degree of moral hazard from low-productivity types. Although the opposite applies to high-productivity types, our simulations suggest the balance of the two effects may well lead to inflated program costs associated with the possibility that the problem of hidden type can exacerbate the problem of moral hazard to an insurer.

Eliminating either the information problem of moral hazard or the problem of adverse selection is costly. Accordingly, one policy consideration for public insurance programs should be to assess the possibility that, when both information asymmetries exist, resolving only one of the two information problems could have benefits exceeding what would be expected in the presence of only one such problem.

On the other hand, a sub-additivity property is also plausible. In our simulations we discovered that with only actions not observable—even if the insurer can set policy parameters, and most importantly the trigger values, according to productivity type—it is still possible that substantial moral hazard costs can arise. Intuitively, and according to our simulations, this result is more likely the higher is the overall coverage level the program offers. When both moral hazard and adverse selection persist, however, since trigger values no longer depend on the productivity type of producers, the yield triggering a claim may be so low from the perspective of the high-productivity type that such a producer finds it worthwhile to switch from the minimum required input level to one that represents an interior optimum. The result can be a strong sub-additivity outcome. In this case, resolving only the hidden type information asymmetry would actually exacerbate program costs and consequently would be a counterproductive policy.

Overall, our simulations demonstrate that an understanding of the way in which producers differ and how their incentives are affected by the contract terms of their insurance policies is critical in characterizing the relationship between program costs and different types of asymmetric information. When both types of asymmetric information persist, whereby various productivity types face the same contract terms, the result can be either an exacerbation or a dilution of the impact of the problems associated with moral hazard. The outcome will depend on the precise nature of the differences between the producers and various other parameters associated with the insurance environment.

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Appendix:

Graphs of the Various Cases of the Beta Distribution Used in the Simulations

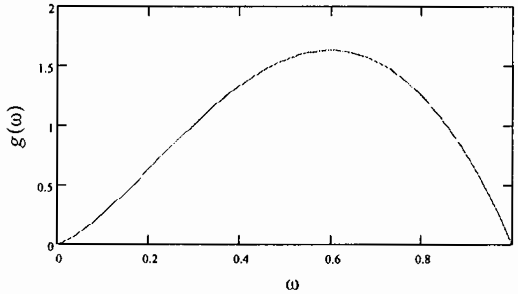

Figure A1. $\alpha = 2.5$, $\beta = 2$

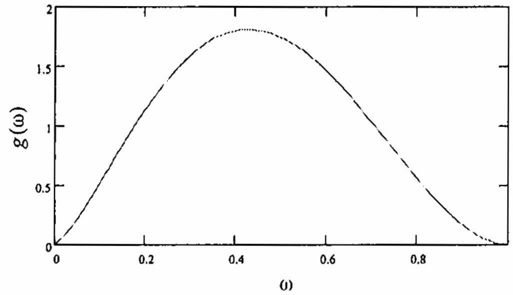

Figure A2. $\alpha = 2.5$, $\beta = 3$

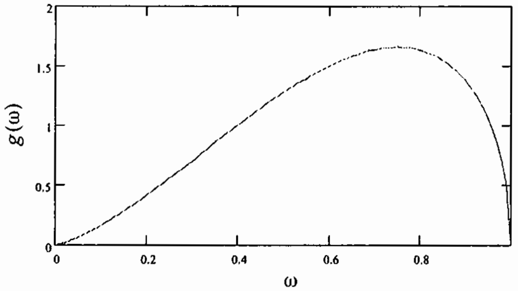

Figure A3. $\alpha = 2.5$, $\beta = 1.5$

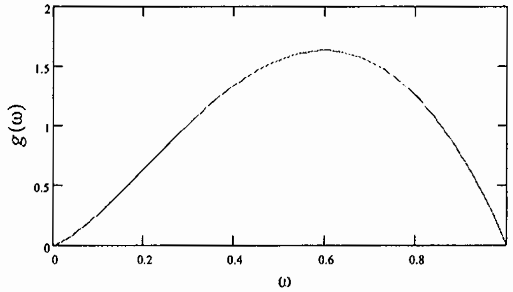

Figure A4. $\alpha = 2$, $\beta = 2$

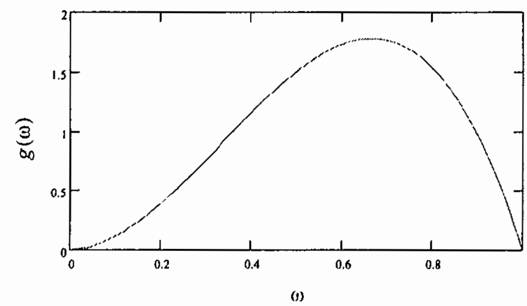

Figure A5. $\alpha = 3$, $\beta = 2$

Evaluating Risk Management Strategies for Pacific Northwest Grain Producers

Larry D. Makus, H. Holly Wang, and Xiaomei Chen

Abstract

A utility maximization model is used to assess alternative risk management portfolios of Pacific Northwest non-irrigated grain producers using three rotational practices. Risk management tools include hedging with wheat futures, yield insurance, two revenue insurance products (with and without price replacement), and government programs under the 2002 Food Security and Rural Investment (FSRI) Act. Government programs account for the primary risk management value of all the analyzed portfolios. The revenue insurance product with price replacement is preferred when available, and yield insurance is preferred over revenue insurance without price replacement. Hedging is not extensively utilized unless government programs are eliminated.

Key words: crop insurance, hedging, non-irrigated crops, risk management

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As the 2007 Farm Bill takes shape, risk management impacts of the 2002 Food Security and Rural Investment (FSRI) Act are likely to take on an increasing level of importance in this policy debate. Additionally, crop insurance programs are likely to continue receiving a significant emphasis for risk management. Testimony from the U.S. Department of Agriculture's (USDA's) Risk Management Agency (RMA) indicates that the use of crop insurance continues to expand, new products including livestock and range-oriented insurance are being implemented, and crop insurance will likely play a major role in the 2007 Farm Bill (Gould, 2007). Thus, the role of government-assisted risk management programs (led by insurance-based products) will likely continue to be a major component of U.S. agriculture.

The Pacific Northwest (PNW) region, represented by the states of Washington, Oregon, and Idaho, provides a unique environment to assess risk management instruments for non-irrigated crop producers. The cropping practices of non-irrigated producers are similar across the three states. Additionally, the region has historically been an area with low utilization rates for traditional Multi-Peril Crop Insurance (MPCI).

That tradition has carried over into the new revenue-based products introduced over the last several years. Using wheat as an example, the national acreage-based crop insurance participation rate was 79.5% for the 2005 crop. However, this rate was 68.3% for the three PNW states, ranging from 59.8% to 75.0%. This level was well below producers in the major wheat producing states such as Kansas (86.5%), North Dakota (98.4%), and Montana (92.2%).

Crop Revenue Coverage (CRC), the primary revenue insurance used for wheat, represented 46.4% of total U.S. insured acres for wheat for the 2005 crop. In contrast, CRC represents just over one-third of Washington and Idaho's insured wheat acres (Oregon is well above the national average for CRC).

Additionally, the PNW also had higher rates for the basic catastrophic coverage (APH-CAT) in 2005, 12.4% of total insured wheat acres, compared to the national level at 8.3% and 1%–5% in Kansas, North Dakota, and Montana [USDA/RMA, 2007; USDA/National Agricultural Statistics Service (NASS), 2006].

PNW non-irrigated grain production regions have three distinct rainfall zones following different rotational practices (Hall, Young, and Walker, 1999): (*a*) dry areas using a winter wheat/summer fallow rotation; (*b*) intermediate rainfall zones using a three-year rotation that includes winter wheat, spring barley, and summer fallow; and (*c*) wet zones with a continuous three-year rotation of winter wheat, spring barley, and a pulse crop like spring peas.

Although changes in production practices are occurring, such as minimum or no-till practices and crop diversification, the three practices discussed above are still dominant (Young, Kwon, and Young, 1994). These production practices also characterize much of the non-irrigated small grain production occurring in many of the other western states.

Whitman is a large county in eastern Washington State with elements of all three agronomic zones. Thus, there is a unique opportunity to conduct an intensive research focus on risk management choices in a single county having applicability to a much broader geographic region.

Accordingly, the objectives of this study are: (*a*) to identify and evaluate alternative risk management strategies under three rotational systems commonly used for non-irrigated crop production in the PNW, (*b*) to evaluate the role of the 2002 FSRI Act and its impact on the use of market pricing instruments and yield insurance products, and (*c*) to assess how modifying selected factors impacting risk management decisions can influence the value of alternative risk management strategies.

Several portfolios of risk management instruments are considered in this research. These portfolios include futures markets, alternative forms of crop insurance (stylized versions of APH, IP, and CRC), and government programs under the 2002 FSRI Act (including direct payments, countercyclical payments, and loan deficiency payments). All of these are assessed in the context of commonly used rotations with one, two, and three crops, which should help capture some diversification impacts on risk management.

This approach is unique because it examines risk choices not from the perspective of selecting crop portfolios given a menu of alternative risk management strategies, but rather, the approach is to hold the crop mix constant and focus on the selection of the utility maximizing parameter values for available combinations of risk management tools. Specifically, given a selection of crops with flexibility to choose risk management tools and coverage levels, what combination and levels would be selected and what are the impacts of the alternative selections?

Evaluating Risk Management Strategies

Much of the previous research conducted on assessing risk management tools for non-irrigated crop producers has focused on the Corn Belt region or the Southern and Northern Plains. Several studies have looked specifically at crop insurance as a risk management tool (Ahsan, Ali, and Kurian, 1982; Heifner and Coble, 1998; Smith and Baquet, 1996; Wang, Hanson, and Black, 2003; Wang et al., 1998; Schnitkey, Sherrick, and Irwin, 2003). An excellent survey of crop insurance was conducted by Knight and Coble in 1997. Other studies have examined the relationship between crop insurance and market-based price risk management tools (Dhuyvetter and Kastens, 1999; Coble, Heifner, and Zuniga, 2000; Pritchett et al., 2004; Rios and Patrick, 2007), or included other important variables like financial leverage (Gloy and Baker, 2003).

Risk management assessment research is limited for the western region, especially for the PNW, although some work has been done. Jones (2002) evaluated risk management strategies using county average yields, but limited attention was paid to risk impact assessment. Ke and Wang (2002) modeled risk management strategies for non-irrigated producers in the PNW, but used parameters from the 1996 farm program and included only two crop rotations.

Our analysis assumes a representative farmer from each of the three PNW production regions discussed above selects a portfolio of risk management instruments at planting time each year. The choice is based on maximizing expected utility of wealth at harvest, denoted by:

(1) $\max E[U(w)]$, and $w = w_0 + \pi$,

where U is a von Neumann-Morgenstern utility function, w is the per acre stochastic terminal wealth, w_0 is an initial wealth level determined by average per acre equity ($550 per acre for Whitman County),[1] and π is the per acre profit function for all farmland in production and fallow. Profit is specified as net revenue generated from cash sales, hedging, and all insurance indemnities, i.e.:

(2) $\pi = NP + FI + (YI \text{ or } RI \text{ or } RIr) + GP$.

The terms in (2) are defined as follows:

$NP =$ $P_L Y - CY$ is the profit from selling crops in the cash market, where P_L is the stochastic local cash price at harvest, Y is the stochastic yield, and CY is the production cost.

$FI =$ $x_1 E(Y)(F - F_0) - CF$ is the net return from hedging, where x_1 is the hedging level chosen at planting time expressed as a ratio of $E(Y)$ or expected yield, F is the stochastic wheat futures price at harvest, F_0 is the planting time futures price, and CF is hedging transaction costs.

$YI =$ $P_b \max[0, x_2 E(Y) - Y] - PRE_y$ is the net return from yield insurance (APH for the crops grown in each of the three regions), where P_b is the insurance base price. The coverage level is denoted by x_2, and is restricted to be either zero or from [0.50 to 0.85] for wheat and barley, and from [0.50 to 0.75] for peas; PRE_y is the insurance premium.

$RI =$ $\max[0, x_3 P_b E(Y) - P_P Y] - PRE_r$ is the net indemnity from revenue insurance without price replacement (a stylized version of IP), x_3 is the coverage level chosen under the same restrictions as yield insurance (YI), P_P is the Portland harvest price for wheat and barley (peas do not have a revenue insurance product), and PRE_r is the revenue insurance premium.

$RIr =$ $\max[0, x_4 P_b E(Y) - P_P Y, x_4 P_P E(Y) - P_P Y] - PRE_{rr}$ is the net indemnity from revenue insurance with price replacement (a stylized CRC), which is only available for wheat. PRE_{rr} is the insurance premium, and x_4 is the selected coverage level as restricted for YI.

[1] Although there are likely differences in average equity across the three agronomic regions of Whitman County, equity is only reported on a county basis in "Representative Farms Economic Outlook for the January 2001 FAPRI/AFPC Baseline" (Richardson et al., 2001).

$GP = DP + CC + LDP$ is the sum of government payments, including direct payments (DP), the countercyclical (CC) payment, and the loan deficiency payment (LDP).

Because the model is simulating farm-level decision makers in Whitman County, the model parameters are set at actual levels. The local cash price (P_L) is the Portland price less \$0.50 per bushel for wheat, Portland price less \$0.43 per bushel for barley, and the local cash price for peas. Production cost is determined by total budgeted rotation production costs of \$230, \$465, and \$707 for the dry, intermediate, and wet regions, respectively (as reported by Painter, Hinman, and Burns, 1995).

The PNW region produces predominantly soft white wheat, which does not have an actively traded futures contract. Therefore, the Chicago Board of Trade (CBOT) futures contract is used for hedging. The planting time futures price is the deferred CBOT September futures during September of the planting year, or \$2.96 per bushel. The futures price at harvest (F) is adjusted to be unbiased, or $E(F) = F_0$, in order to avoid a speculating effect from the decision model. Hedging transaction costs are set at \$0.017 per bushel based on a \$50 per contract commission, a margin of \$745, and an interest rate of 5%.

The insurance base price is the CBOT September wheat futures price plus a Portland basis of \$0.45 for wheat (\$3.41/bushel), 85% of the September corn futures price during February for barley (\$1.90/bushel), and the expected local cash price for peas (\$7.49/cwt). These values are established by the insurance products used to determine insurance indemnities.

The direct payment (DP) is \$0.52 per bushel for wheat and \$0.24 per bushel for barley. The actual payment is based on 85% of the base acres times the base yield. The base yield for DP is equal to the "old" base, which is set at 90% of the expected 2002 yield, or $E(Y)$. The countercyclical payment (CC) for wheat is equal to $\max[0; \$3.86 - (\max(P_{aw}, P_{nl}) + DP]$ times 85% of the base yield. The base yield is updated for the CC payment, and equal to 93.5% of the expected yield, or $E(Y)$. P_{aw} is the Portland cash wheat price at harvest adjusted for location and time based on a historical average to represent the season average price for wheat. P_{nl} is the national loan rate of \$2.80. The CC payment for barley is $\max[0; \$2.21 - (\max(P_{ab}, P_{nl}) + DP]$ times 85% of the base. The variables (P_{ab}, P_{nl}) are defined for barley instead of wheat (Portland price less \$0.43 to represent the U.S. season average price and a loan rate of \$1.88 per bushel). There are no DP or CC payments for peas. The LDP is equal to $\max(0; LR - P_L)Y$, where LR is \$2.90 per bushel for wheat, \$2.14 per bushel for barley, and \$6.33 per cwt for peas. P_L is the local price as defined earlier, and Y is actual yield.

Per rotation-based profit in the expected utility function is adjusted to a consistent one-acre return. The farmer is assumed to have constant relative risk aversion, with the utility functional form expressed as:

(3) $U(w) = (1 - \theta)^{-1} w^{(1-\theta)}$,

where θ is the relative risk-aversion coefficient. The value of the risk-aversion coefficient is set at $\theta = 2$, which is based on previous research (Wang, Hanson, and Black, 2003; Coble, Heifner, and Zuniga, 2000; Pope and Just, 1991).

Model Input Data

To accurately assess the risk environment, appropriate yield and price distributions must be determined. Joint distributions of prices and yields are simulated for the 2002 crop year relevant to the farms in the three Whitman County rainfall areas. Crop yield distributions for soft white winter wheat, spring barley, and dry peas are simulated based on a combination of farm-level and county-level yield data.

Farm-level yields are collected and maintained by RMA to establish a yield base for crop insurance purposes. Yield histories are uniquely identified using a policy number. Each policy number has a state, county, and crop identifier, and the 2002 files also include a legal description of the insured unit. Thus, it is possible to segregate Whitman County farm-level actual yields by commodity, and separate geographically within the county using the section, township, and range descriptors of the insured units (USDA/RMA, 2003).

This data set maintains a maximum of 10 years of yield observations (2001 is the most recent year) as required to establish a complete yield base, although the 10 observed yields may not cover the most recent 10 years. Only actual yield observations are used in this analysis, and those with less than six actual yield observations are deleted from the data set.

These actual on-farm yield data represent the first step used to establish yield distributions for each commodity (winter wheat, spring barley, and dry peas) within the three rainfall zones (dry, intermediate, and wet). The actual yield observations included: (*a*) wheat in the dry region (78 observations), (*b*) wheat in the intermediate region (469 observations), (*c*) barley in the intermediate region (298 observations), (*d*) wheat in the wet region (543 observations), (*e*) barley in the wet region (311 observations), and (*f*) peas in the wet region (258 observations).

A longer period (64 years, 1936–2000)[2] of county-level yield data is used to determine trend and distributional form. A linear trend (with an autoregressive term in the case of wheat) is estimated for each crop. Wheat in the PNW often follows summer fallow, which means a high yield (good moisture) year in period t likely impacts yield in year $t+1$. A field that is fallow collects moisture in year t (the "good" moisture year), and the yield in year $t+1$ is improved. The opposite argument follows for those years with low moisture.

The distributional form of crop yield data continues to be a debated issue (Just and Weninger, 1999; Ker and Coble, 2003; Ramirez, Misra, and Field, 2003). Skewed distributional forms have been suggested (Hennessy, Babcock, and Hayes, 1997; Moss and Shonkwiler, 1993; Nelson and Preckel, 1989), but the normal distribution is also supported (Just and Weninger, 1999). Several normality tests (Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling) conducted on yield residuals after adjusting for trend indicate normality cannot be rejected for wheat. Therefore, a normal distribution is simulated for wheat yield.

Barley and pea yields also passed the normality tests after removal of one severe drought year—1977. Although only one severe drought year was observed over the 64 years, the possibility of a drought cannot be excluded. When drought occurs, the yield may also show a normal distribution, but with a much lower mean. The final model used for simulating barley and pea yields is a mixed distribution with two normal components. The second normal component has a lower mean, a modified standard deviation, and a probability of one in 64 of occurring. The mean yield for the drought year (the second normal distribution) is the 1977 barley and pea county means, and the variance is calculated by assuming zero as the five-percentile lower bound for the two crops.

The representative farm-level yields for each precipitation area are assumed to follow the same trend and distributional forms (normal for wheat and the mixed normal for barley and peas) as the long-term county yields. However, these farm-level yields are adjusted for mean and variance based on the detrended farm-level yield data for each precipitation area. The farm-level yield data from RMA are first detrended by the county yield results,

[2] The trend in county yield was established using as long a period of data as was available, which started in 1936 for Whitman County.

and means and variances for each crop from each region are determined from these detrended data. The resulting mean and variance levels are then imposed as farm-level yield parameters when crop yields are simulated for each of the three regions.

Generalized autoregressive conditional heteroskedastic (GARCH) models have been commonly used for commodity cash and futures prices. For this analysis, wheat cash and futures prices are estimated with a bivariate GARCH model. Barley and dry peas are estimated separately using a univariate GARCH model. Price models are estimated from weekly price data covering the four years prior to the expected planting date for the 2002 crop (September 1998 to August 2001 for wheat futures and cash prices, and April 1999 to March 2002 for barley and pea cash prices). Wheat cash and futures prices for the first week of September 2001 ($3.69 and $2.96 per bushel, respectively) are the initial values for simulating their joint distribution for the 2002 harvest period. Barley and pea initial values are cash prices for the first week of April 2002 ($2.22 per bushel and $7.39 per cwt, respectively). Both periods represent planting times for the respective crops.

An empirical distribution with 2,000 samples is simulated for each crop's price and yield. The independently simulated distributions are converted into joint normal distributions using a linear transformation to impose the estimated correlation structure. Descriptive statistics for the simulated price and yield data are presented in Table 1, along with correlation values for the simulated joint distributions.

Results

The optimization choices suggested by decision model (1) are solved numerically using GAUSS. Because a closed-form solution doesn't exist for this complex model, a numerical technique is used. GAUSS uses a set of initial values for the choice variables (e.g., $x_1 = 0$ and $x_2 = 0.6$) to calculate 2,000 profit values based on the simulated price/yield sample. GAUSS then puts these profit values into the utility function to obtain 2,000 utility values and uses a sample mean to represent a single $E(U)$ value for these initial values.

Next, GAUSS searches for other choice variable values (hedging level, insurance level, and insurance type) to update the initial set to obtain a higher $E(U)$ value. The procedure stops at the choice variable values when $E(U)$ can no longer be made larger. The choice variable values are chosen from the allowable range (50% to 75% or 85% for crop insurance, and any hedging level for futures). This optimized $E(U)$ is then compared to the $E(U)$ when crop insurance coverage is set at zero (not participating) while allowing futures to optimize. The larger of the two is the final result.

The insurance premium is based on an actuarially fair level, which is defined as the expected per acre indemnity payment. GAUSS calculates 2,000 random indemnity payments based on each insurance coverage level (say 53%) using the price-yield realizations, and then takes the average indemnity payment as the actuarially fair premium in the optimization procedure. Therefore, the premium is variable corresponding to the chosen coverage level and is simultaneously determined in the optimization procedure.

Equivalent variation (EV) is utilized to evaluate alternative risk management portfolios (relative to cash sales at harvest) under specified scenario changes. EV is the amount of money (per acre) that would have to be provided to the farmer to keep him or her at the same level of utility as providing the farmer with the specified risk management portfolio. EV can be calculated by solving:

$$(4) \quad E[u(w_0 + \pi^*)] = E[u(w_0 + \pi_0 + EV)],$$

Table 1. Descriptive Statistics for Price and Yield Simulated Data for the Dry, Intermediate, and Wet Areas in Whitman County, Washington

				Correlation Coefficients						
Region / *Variable*	**Mean**	**Std. Dev.**	**Skewness**	**Wheat FP**	**Wheat CP**	**Wheat Yld**	**Barley CP**	**Barley Yld**	**Pea CP**	**Pea Yld**
Dry Region:										
Wheat FP	2.96	0.75	0.70	1.00	0.48	0.03	NA	NA	NA	NA
Wheat CP	3.69	0.61	0.52	0.48	1.00	0.03	NA	NA	NA	NA
Wheat Yld	68.94	15.51	0.04	-0.03	-0.03	1.00	NA	NA	NA	NA
Intermediate Region:										
Wheat FP	2.96	0.75	0.70	1.00	0.48	-0.02	0.31	-0.01	NA	NA
Wheat CP	3.69	0.61	0.52	0.48	1.00	-0.04	0.63	-0.01	NA	NA
Wheat Yld	75.42	14.31	0.00	-0.02	-0.04	1.00	-0.04	0.27	NA	NA
Barley CP	2.22	0.21	0.23	0.31	0.63	-0.04	1.00	-0.02	NA	NA
Barley Yld	71.34	19.58	-0.38	-0.01	-0.01	0.27	-0.02	1.00	NA	NA
Wet Region:										
Wheat FP	2.96	0.75	0.70	1.00	0.48	0.00	0.31	0.02	0.02	0.02
Wheat CP	3.69	0.61	0.52	0.48	1.00	-0.03	0.63	0.00	-0.02	-0.02
Wheat Yld	89.16	14.97	0.04	0.00	-0.03	1.00	-0.02	0.11	-0.01	0.38
Barley CP	2.22	0.21	0.23	0.31	0.63	-0.02	1.00	0.03	0.04	0.02
Barley Yld	73.17	18.69	-0.43	0.02	0.00	0.11	0.03	1.00	0.01	0.21
Pea CP	7.39	0.63	0.16	0.02	0.02	-0.01	0.04	0.01	1.00	-0.04
Pea Yld	19.85	5.64	-0.20	0.02	-0.02	0.38	0.03	0.21	-0.04	1.00

Source: Simulated price and yield distributions used for model input.

Notes: Wheat FP is wheat futures price ($/bushel), *Wheat CP* is wheat cash price ($/bushel), *Wheat Yld* is wheat yield (bushels/acre), *Barley CP* is barley cash price ($/bushel), *Barley Yld* is barley yield (bushels/acre), *Pea CP* is pea cash price ($/cwt), *Pea Yld* is pea yield (cwt/acre), and NA = not applicable.

where π^* is the net return from using a specific risk management portfolio at the optimum level, and π_0 is the net return from selling in the cash market at harvest [*NP* in equation (2)].

The alternative portfolios include each risk management tool separately, and several selected combinations of crop insurance and/or hedging (Tables 2–4). The alternative risk management portfolios are assessed under several different scenarios as a sensitivity analysis. The base scenario is designed to represent the current situation, with actuarially fair premiums and premium subsidies representing 2002 levels. All government program payments are in place, and hedging with futures involves a transaction cost of $0.017 per bushel.

An increased risk-aversion scenario looks at the impact of assuming a more risk-averse farmer (raising the risk-aversion coefficient from 2 to 3). Three scenarios are analyzed to evaluate the impact of altering the structure of crop insurance premiums relative to the base scenario. The "30% Premium Load with Premium Subsidy" scenario assigns a 30% premium load and retains the premium subsidy. Another scenario ("No Premium Subsidy and Actuarially Fair Premium") has no premium subsidy and no premium load. A "No Premium Subsidy with a 30% Premium Load" scenario eliminates premium subsidies, and assigns a 30% load. To assess the impact of transaction costs on hedging, one scenario includes the use of futures with the base scenario hedging cost of $0.017 per bushel eliminated. Another scenario examines the impact of eliminating all government payments [the *GP* component of equation (2)].

Another interesting question is what the optimum insurance coverage level would be if the current constraints (generally 85%) were relaxed. Although not explicitly analyzed as a specific scenario in our analysis, some discussion of this relaxation is provided. Some of the scenario results may not be discussed or included in the tables if the changes associated with the scenario have no impact on the results. (Complete results are available from the authors on request.) Results from each region are briefly summarized, followed by some general overall conclusions.

Dry Region

Seven alternative risk management portfolios are analyzed for the dry region, which has only one crop plus fallow (Table 2). For the base scenario, CRC with a coverage level of 0.85 is identified as the optimum strategy based on the highest EV value. Hedging with futures reflects a hedge ratio of zero, so "CRC+Futures" provides the same result as CRC alone. This outcome is different when compared to earlier results reported by Coble, Heifner, and Zuniga (2000) or Ke and Wang (2002). Results from both studies suggest a larger role for hedging when CC payments were not available.

These differing results suggest CC payments protect farmers from price risk at no cost, leaving little room for the futures market. CRC has a price and yield insurance component (relative to APH which only has a yield insurance component), has a price replacement feature (relative to IP), and tends to have the largest proportional premium subsidy.

The EV values for the insurance-based alternatives in the base scenario range from \$26.39 to \$27.28, and are primarily driven by government program payments with a total EV of \$24.66 (the "Only GP" alternative). As indicated by equation (4), this result suggests a payment of \$24.66 would have to be added to the profit associated with selling on the cash market to keep the farmer at the same level of utility provided by the use of government programs as a risk management tool. The values of the alternative crop insurance products (measured by subtracting total EV from the EV associated with government payments only or "EV w/o GP") are between \$1.74 and \$2.63.

Results from the sensitivity scenarios indicate the EV values are relatively insensitive to the change in risk aversion, insurance premium modifications, or the elimination of futures transaction costs. Increasing the risk-aversion coefficient to 3 means the more risk-averse producer has a higher EV for all risk management portfolios. Raising the premium by adding a 30% premium load reduces the level of insurance slightly, and reduces EV values. Eliminating the premium subsidy reduces the EV values, but alternative insurance products are still used at the maximum level of 85%. For all of the alternative scenarios, the rank-order of the alternative insurance products remains essentially the same as the base scenario.

Results for two analyzed scenarios are not presented in Table 2. When the premium subsidy is eliminated and a premium load is assigned ("No Premium Subsidy with a 30% Premium Load"), all insurance coverage levels go to zero and hedge ratios remain at zero. Eliminating futures transaction costs produces the same outcome for each portfolio alternative as the base scenario, with all hedge ratios remaining at zero.

In the scenario with no government programs, futures are utilized, although at fairly low levels. Hedging still has a transaction cost and basis risk, which seems to limit the use of futures. Previous research on cross-hedging PNW soft white wheat also suggests optimum hedge ratios are fairly low when using the CBOT (Chen, Makus, and Wang, 2004). The subsidized revenue insurance products also provide protection against price risk.

Table 2. Optimization Results for the Winter Wheat/Summer Fallow Rotation: Dry Region

	Base Scenario				Increase Risk-Aversion Coefficient to 3			
Risk Mgmt. Alternative	**Hedge Ratio**	**Insurance Coverage**	**EV ($/acre)**	**EV w/o GP ($/acre)**	**Hedge Ratio**	**Insurance Coverage**	**EV ($/acre)**	**EV w/o GP ($/acre)**
Only GP	NA	NA	24.66	0	NA	NA	24.83	0
Futures	0	NA	24.66	0	0	NA	24.83	0
APH	NA	0.85	26.59	1.94	NA	0.85	27.00	2.17
IP	NA	0.85	26.39	1.74	NA	0.85	26.76	1.93
CRC	***NA***	***0.85***	***27.28***	***2.63***	***NA***	***0.85***	***27.73***	***2.90***
APH+Futures	0	0.85	26.59	1.94	0	0.85	27.00	2.17
IP+Futures	0	0.85	26.39	1.74	0	0.85	26.76	1.93
CRC+Futures	0	0.85	27.28	2.63	0	0.85	27.73	2.90

	30% Premium Load with Premium Subsidy				No Premium Subsidy and Actuarially Fair Premium			
Risk Mgmt. Alternative	**Hedge Ratio**	**Insurance Coverage**	**EV ($/acre)**	**EV w/o GP ($/acre)**	**Hedge Ratio**	**Insurance Coverage**	**EV ($/acre)**	**EV w/o GP ($/acre)**
Futures	0	NA	24.66	0	0	NA	24.66	0
APH	NA	0.83	25.92	1.26	NA	0.85	25.11	0.46
IP	NA	0.82	25.78	1.12	NA	0.85	25.04	0.38
CRC	***NA***	***0.82***	***26.35***	***1.69***	***NA***	***0.85***	***25.18***	***0.53***
APH+Futures	0	0.83	25.91	1.26	0	0.85	25.11	0.45
IP+Futures	0	0.82	25.78	1.12	0	0.85	25.04	0.38
CRC+Futures	0	0.82	26.35	1.69	0	0.85	25.18	0.53

	No Government Program		
Risk Mgmt. Alternative	**Hedge Ratio**	**Insurance Coverage**	**EV w/o GP ($/acre)**
Futures	-0.11	NA	0.02
APH	NA	0.85	1.91
IP	NA	0.85	1.87
CRC	NA	0.85	2.69
APH+Futures	-0.12	0.85	1.93
IP+Futures	-0.06	0.85	1.87
CRC+Futures	***-0.09***	***0.85***	***2.70***

Notes: The first five portfolios presented for each scenario represent each risk management tool separately. Government payments only, futures only, and each insurance product are presented separately. The "Only GP" portfolio is not repeated for all scenarios since its value is not impacted by the scenario changes. The next three portfolios are insurance products combined with hedging using futures. The column labeled "EV w/o GP" reflects the value of the portfolio after the EV from government programs is removed. NA = not applicable.

The futures position is smaller with revenue insurance in place when compared to yield insurance. Using APH with futures results in a short futures position on 12% of expected production. The optimum portfolio of CRC with futures has a hedge ratio of -0.09. The low EV values of the "No Government Program" scenario again emphasize the dominant role government payments play in risk management.

For the single crop rotation (dry region), there is generally a small difference between strategies. Government payments provide the primary source of EV. Part of this EV clearly comes from price risk protection, but most comes from the significant increase in expected income. The per acre expected income transfer from government payments, or $E(GP)/2$, is \$24.28.[3] Given an EV per acre for "Only GP" of \$24.66, this leaves an additional value of \$0.38 for price risk protection. CRC is typically the preferred insurance product, and no insurance is purchased without a subsidized premium under a premium regime that assumes a 30% load as part of the cost. Hedging only emerges when government payments are completely eliminated, and then at fairly low levels. Increasing the level of risk aversion, while increasing EVs for all portfolios, has no impact on the optimum portfolio mix.

Finally, the question about whether or not the maximum allowable insurance coverage level likely impacts the grower's insurance choice for the alternative scenarios is addressed. Although not explicitly analyzed in the model, some potential outcomes can be suggested. First, whenever the 30% premium load is present (whether the premium is subsidized or not), the optimal coverage level is below the maximum allowable level of 85% for wheat. Therefore, the constraint appears to be nonbinding.

Second, for the case of an actuarially fair premium with no subsidy, a risk-averse grower will choose a coverage level to represent the maximum possible yield, which is a coverage level above 100% of expected yield. An actuarially fair premium does not impact the post-premium mean revenue no matter what coverage level is selected. Choosing a coverage level that represents the maximum possible yield uses insurance to completely eliminate any risk associated with yield variability. Since yield and price are uncorrelated in this situation, the coverage level is independent of the price risk and price instruments.

Finally, under the base scenario where the current subsidy is provided with no premium load, the optimal coverage choice is driven by the subsidy schedule. The current subsidy schedule is regressive, from 67% at the 50% coverage level down to 38% at the 85% coverage level. A tradeoff exists between higher protection and the higher subsidy. Although not explicitly included in our analysis, analyzing higher insurance coverage levels in this scenario would likely provide results dependent on the assumed level of subsidy for coverage levels above the maximum currently allowed. Similar reasoning applies to the "No Government Program" and "Increased Risk Aversion" scenarios.

Intermediate Region

Thirteen portfolios are analyzed for the intermediate region (two crops) using the same seven scenarios (Table 3). For the base scenario and the alternative scenarios, futures or combinations using futures result in hedge ratios of zero. Outcomes for all the combination strategies that include futures are exactly the same as the corresponding crop insurance combinations without futures. Therefore, portfolios using a combination of crop insurance and hedging with futures are not presented for any of the scenarios reported in Table 3. The one exception is for the scenario where government programs are eliminated, when hedging begins to play a role.

CRC for wheat combined with APH for barley represents the optimum risk management portfolio for the intermediate region's base scenario. The maximum 85% insurance coverage level is utilized for both crops. Results from the dry region also rank CRC first, followed by APH and IP. Since there is no CRC for barley, APH is selected in the optimum portfolio for the intermediate region. The EV values for the insurance-based alternatives in the base scenario range from \$34.27 to \$35.05,

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[3] The income from government payments is the *GP* value in equation (2), and must be adjusted to a per acre basis. For the dry region, the expected value of *GP* is divided by 2 since the $E(GP)$ is the total from two acres of farmland, although one acre is fallow. In the intermediate and wet areas, the total $E(GP)$ from either two crops or three crops is divided by 3.

and are primarily driven by government program payments with a total EV of \$32.56 (the "Only GP" alternative). EV values of the alternative crop insurance products are between \$1.71 and \$2.49.

The alternative scenario results for the intermediate region are similar to the dry region. Increasing the risk-aversion coefficient or moving to a higher insurance premium structure does not alter the rank-order of the alternatives, produce any change in the level of hedging, or significantly impact the insurance coverage level. More risk-averse producers value the insurance products at a higher level (increased EV), and higher premiums lower the EV levels. For the same reasons as in the dry region, results for two analyzed scenarios, "No Premium Subsidy with a 30% Premium Load" and no futures transaction cost, are not presented.

The EV value is lower for the intermediate area's optimum portfolio in the base scenario compared to the dry region even though the barley coverage is also 0.85 and a subsidy is provided. Three reasons may explain this observation. First, when a yield loss occurs, the indemnity payment for wheat is calculated on a base price of \$3.41, which is fairly close to the mean cash price of \$3.69 (92%). This represents more protection when compared to barley, where the base price is only \$1.90 and the expected cash price is \$2.22 (about 85%). Therefore, barley insurance has a weaker risk protection effect than wheat. Second, there may be a slight diversification effect, because the correlations between wheat and barley yields and prices are quite low. This diversification effect means the original risk exposure without using any instruments is lower for the intermediate area relative to the dry area. Thus, value of the risk management instruments is lower. Third, barley does not have CRC and the APH receives a lower subsidy.

When government programs are eliminated for the intermediate region, hedging begins to play a role in portfolio selection. The futures-based portfolio (hedging wheat) has a hedge ratio of -0.16, implying about 16% of the expected yield is hedged with a short futures position. The optimum risk management portfolio becomes the combination of CRC for wheat, APH for barley, and hedging 13% of expected wheat yield. As was true for the dry region, eliminating government programs has a substantial downward impact on the EV values. Again, results clearly indicate government programs are the dominant price risk management tool for non-irrigated PNW grain producers. The increased hedging level in the intermediate region compared with the dry region suggests farmers may cross-hedge barley on wheat futures. Barley and wheat cash prices are positively correlated.

Generally, results for the intermediate region with a two-crop/fallow rotation are similar to the single crop region. There appears to be some evidence of a diversification impact on risk associated with adding the additional crop as indicated by the lower EV levels, but not on insurance participation levels which are primarily driven by the premium subsidies. APH for barley is preferred over the available revenue product (IP).

Results similar to those for the dry region can be suggested regarding the impact of removing the constraints on insurance coverage levels. Additionally, the base scenario results for barley indicate coverage levels are at 84% or 85%. This suggests that if the subsidy rate drops below the current level of 38% for higher coverage levels, the optimal choice still may be about 85%.

Wet Region

The three-crop rotation in the wet region means each portfolio must include a combination of the three crops. Seven scenarios are analyzed, with six presented in Table 4. Outcomes for all the combination strategies that include futures and crop insurance are the same as the insurance combinations without futures (hedge ratios are zero). Therefore, portfolios using a combination of crop insurance and hedging with futures are not presented.

Table 3. Optimization Results for the Winter Wheat/Spring Barley/Summer Fallow Rotation: Intermediate Region

	Base Scenario				
		Insurance Coverage			
Risk Management Alternative	**Hedge Ratio**	**Wheat**	**Barley**	**EV ($/acre)**	**EV w/o GP ($/acre)**
Only GP	NA	NA	NA	32.56	0
Futures_W	0	NA	NA	32.56	0
APH_W&B	NA	0.85	0.85	34.58	2.02
IP_W&B	NA	0.85	0.84	34.27	1.71
CRC_W+APH_B	***NA***	***0.85***	***0.85***	***35.05***	***2.49***
CRC_W+IP_B	NA	0.85	0.84	34.76	2.20
APH_W+IP_B	NA	0.85	0.84	34.29	1.73
IP_W+APH_B	NA	0.85	0.85	34.56	2.00

	30% Premium Load with Premium Subsidy				
		Insurance Coverage			
Risk Management Alternative	**Hedge Ratio**	**Wheat**	**Barley**	**EV ($/acre)**	**EV w/o GP ($/acre)**
Futures_W	0	NA	NA	32.56	0
APH_W&B	NA	0.84	0.80	33.89	1.33
IP_W&B	NA	0.83	0.79	33.69	1.13
CRC_W+APH_B	***NA***	***0.83***	***0.79***	***34.17***	***1.61***
CRC_W+IP_B	NA	0.83	0.79	33.99	1.43
APH_W+IP_B	NA	0.84	0.79	33.71	1.15
IP_W+APH_B	NA	0.83	0.80	33.87	1.31

	No Government Program			
		Insurance Coverage		
Risk Management Alternative	**Hedge Ratio**	**Wheat**	**Barley**	**EV w/o GP ($/acre)**
Futures_W	-0.16	NA	NA	0.02
APH_W&B	NA	0.85	0.85	1.97
IP_W&B	NA	0.85	0.84	1.81
CRC_W+APH_B	NA	0.85	0.85	2.50
CRC_W+IP_B	NA	0.85	0.84	2.26
APH_W+IP_B	NA	0.85	0.84	1.72
IP_W+APH_B	NA	0.85	0.85	2.07
APH_W&B+Futures	-0.17	0.85	0.85	1.98
IP_W&B+Futures	-0.10	0.85	0.84	1.82
CRC_W+APH_B+Futures	***-0.13***	***0.85***	***0.85***	***2.52***
CRC_W+IP_B+Futures	-0.12	0.85	0.84	2.27
APH_W+IP_B+Futures	-0.16	0.85	0.84	1.74
IP_W+APH_B+Futures	-0.11	0.85	0.85	2.07

Notes: The first two portfolios represent government payments only (wheat and barley) and futures only for wheat. The next six represent combinations of crop insurance products for wheat (APH, CRC, and IP) and barley (AP and IP). The next six are combinations of crop insurance products and futures. These last six are only included under the "No Government Program" scenario because the hedge ratios were consistently zero for all the other scenarios. The "Only GP" portfolio is not repeated for all scenarios since its value is not impacted by the scenario changes. The column labeled "EV w/o GP" reflects the value of the portfolio after the EV from government programs is removed. NA = not applicable.

[table extended ›]

Table 3. Extended

	Increase Risk-Aversion Coefficient to 3				
		Insurance Coverage			
Risk Management Alternative	**Hedge Ratio**	**Wheat**	**Barley**	**EV ($/acre)**	**EV w/o GP ($/acre)**
Only GP	NA	NA	NA	32.75	0
Futures_W	0	NA	NA	32.75	0
APH_W&B	NA	0.85	0.85	34.98	2.23
IP_W&B	NA	0.85	0.85	34.63	1.88
CRC_W+APH_B	***NA***	***0.85***	***0.85***	***35.47***	***2.72***
CRC_W+IP_B	NA	0.85	0.85	35.16	2.41
APH_W+IP_B	NA	0.85	0.85	34.67	1.92
IP_W+APH_B	NA	0.85	0.85	34.95	2.20

	No Premium Subsidy and Actuarially Fair Premium				
		Insurance Coverage			
Risk Management Alternative	**Hedge Ratio**	**Wheat**	**Barley**	**EV ($/acre)**	**EV w/o GP ($/acre)**
Futures_W	0	NA	NA	32.56	0
APH_W&B	NA	0.85	0.85	32.97	0.40
IP_W&B	NA	0.85	0.85	32.93	0.37
CRC_W+APH_B	***NA***	***0.85***	***0.85***	***33.01***	***0.45***
CRC_W+IP_B	NA	0.85	0.85	33.00	0.44
APH_W+IP_B	NA	0.85	0.85	32.97	0.40
IP_W+APH_B	NA	0.85	0.85	32.94	0.38

The "No Government Program" scenario is the one exception, because hedging takes place when government payments are eliminated.

Similar to results for the intermediate zone, the optimum portfolio for the base scenario includes CRC for wheat and APH for the other two crops (barley and peas). APH is apparently preferred over IP for barley, likely for the same reasons discussed regarding the intermediate region. The EV values for the insurance-based alternatives in the base scenario range from $39.07 to $39.83, and are again primarily driven by government program payments with a total EV of $36.34 (the "Only GP" alternative). EV values for the alternative crop insurance products without government payments are between $2.73 and $3.49. Peas are consistently insured at the maximum allowable level (0.75) in the base scenario, suggesting producers utilize the higher coverage levels when subsidies provide premiums below actuarially fair levels.

The impacts of increasing the risk-aversion coefficient and altering the premium structure are similar to the other two regions. The ranking of the portfolios remains essentially unchanged when these scenario changes are implemented. EV values are slightly increased when the risk-aversion coefficient increases. Insurance coverage levels stay at or near the maximum coverage levels for the higher premium structure, with lower EVs to reflect the higher insurance cost.

The government program EV increases by almost $4 (to $36.34) for the wet region relative to the intermediate region. This increase is primarily a result of replacing the fallow acres with pea acres that are eligible for the loan deficiency payment, so expected income from government payments is higher.

Table 4. Optimization Results for the Winter Wheat/Spring Barley/Peas Rotation: Wet Region

Risk Management Alternative	Hedge Ratio	Insurance Coverage: Wheat	Insurance Coverage: Barley	Insurance Coverage: Peas	EV ($/acre)	EV w/o GP ($/acre)
Base Scenario						
Only GP	NA	NA	NA	NA	36.34	0
Futures_W	0	NA	NA	NA	36.34	0
APH_W&B&P	NA	0.85	0.85	0.75	39.34	3.00
IP_W&B+APH_P	NA	0.85	0.85	0.75	39.15	2.81
CRC_W+APH_B&P	***NA***	***0.85***	***0.85***	***0.75***	***39.83***	***3.49***
CRC_W+IP_B+APH_P	NA	0.85	0.85	0.75	39.55	3.21
APH_W&P+IP_B	NA	0.85	0.85	0.75	39.07	2.73
IP_W+APH_B&P	NA	0.85	0.85	0.75	39.46	3.09
30% Premium Load with Premium Subsidy						
Futures_W	0	NA	NA	NA	36.34	0
APH_W&B&P	NA	0.85	0.80	0.75	38.49	2.15
IP_W&B+APH_P	NA	0.84	0.80	0.75	38.36	2.02
CRC_W+APH_B&P	***NA***	***0.84***	***0.80***	***0.75***	***38.78***	***2.44***
CRC_W+IP_B+APH_P	NA	0.84	0.80	0.75	38.60	2.26
APH_W&P+IP_B	NA	0.85	0.80	0.75	38.32	1.98
IP_W+APH_B&P	NA	0.84	0.80	0.75	38.53	2.19

Risk Management Alternative	Hedge Ratio	Insurance Coverage: Wheat	Insurance Coverage: Barley	Insurance Coverage: Peas	EV w/o GP ($/acre)
No Government Program					
Futures_W	-0.19	NA	NA	NA	0.04
APH_W&B&P	NA	0.85	0.85	0.75	3.00
IP_W&B+APH_P	NA	0.85	0.85	0.75	3.00
CRC_W+APH_B&P	NA	0.85	0.85	0.75	3.60
CRC_W+IP_B+APH_P	NA	0.85	0.85	0.75	3.37
APH_W&P+IP_B	NA	0.85	0.85	0.75	2.77
IP_W+APH_B&P	NA	0.85	0.85	0.75	3.24
APH_W&B&P+Futures	-0.20	0.85	0.85	0.75	3.04
IP_W&B+APH_P+Futures	-0.13	0.85	0.85	0.75	3.02
CRC_W+APH_B&P+Futures	***-0.17***	***0.85***	***0.85***	***0.75***	***3.63***
CRC_W+IP_B+APH_P+Futures	-0.16	0.85	0.85	0.75	3.39
APH_W&P+IP_B+Futures	-0.19	0.85	0.85	0.75	2.81
IP_W+APH_B&P+Futures	-0.14	0.85	0.85	0.75	3.26

Notes: The pattern of presentation is similar to Tables 2 and 3. The scenario for "No Premium Subsidy and 30% Premium Load" is presented in this table because a small amount of wheat APH is used without the subsidy. The portfolios representing combinations of futures and crop insurance are not included in the first four scenarios as is true for the no premium subsidy with load scenario because the hedge ratios are zero. Each portfolio includes all three crops. NA = not applicable.

[table extended ›]

Table 4. Extended

Risk Management Alternative	Hedge Ratio	Insurance Coverage			EV ($/acre)	EV w/o GP ($/acre)
		Increase Risk-Aversion Coefficient to 3				
		Wheat	Barley	Peas		
Only GP	NA	NA	NA	NA	36.62	0
Futures_W	NA	NA	NA	NA	36.62	0
APH_W&B&P	NA	0.85	0.85	0.75	40.00	3.38
IP_W&B+APH_P	NA	0.85	0.85	0.75	39.78	3.16
CRC_W+APH_B&P	***NA***	***0.85***	***0.85***	***0.75***	***40.52***	***3.90***
CRC_W+IP_B+APH_P	NA	0.85	0.85	0.75	40.22	3.60
APH_W&P+IP_B	NA	0.85	0.85	0.75	39.71	3.09
IP_W+APH_B&P	NA	0.85	0.85	0.75	40.08	3.46
		No Premium Subsidy and Actuarially Fair Premium				
Risk Management Alternative	**Hedge Ratio**	**Insurance Coverage**			**EV ($/acre)**	**EV w/o GP ($/acre)**
		Wheat	**Barley**	**Peas**		
Futures_W	NA	NA	NA	NA	36.34	0
APH_W&B&P	NA	0.85	0.85	0.75	37.04	0.70
IP_W&B+APH_P	NA	0.85	0.85	0.75	37.02	0.68
CRC_W+APH_B&P	***NA***	***0.85***	***0.85***	***0.75***	***37.10***	***0.76***
CRC_W+IP_BB+APH_P	***NA***	***0.85***	***0.85***	***0.75***	***37.10***	***0.76***
APH_W&P+IP_B	NA	0.85	0.85	0.75	37.05	0.71
IP_W+APH_B&P	NA	0.85	0.85	0.75	37.02	0.68
		No Premium Subsidy and 30% Premium Load				
Risk Management Alternative	**Hedge Ratio**	**Insurance Coverage**			**EV ($/acre)**	**EV w/o GP ($/acre)**
		Wheat	**Barley**	**Peas**		
Futures_W	0	NA	NA	NA	36.34	0
APH_W&B&P	NA	0.51	0.00	0.00	36.35	0.01
IP_W&B+APH_P	NA	0.50	0.00	0.00	36.34	0.00
CRC_W+APH_B&P	NA	0.50	0.00	0.00	36.34	0.00
CRC_W+IP_B+APH_P	NA	0.50	0.00	0.00	36.34	0.00
APH_W&P+IP_B	NA	0.51	0.00	0.00	36.35	0.01
IP_W+APH_B&P	NA	0.50	0.00	0.00	36.34	0.00

EVs of the alternative insurance products are also higher compared to both the dry and intermediate areas, suggesting inclusion of the pea APH improves insurance portfolio value. This likely comes from two sources: increased cropping intensity and the pea APH which has a high value when compared to the wheat and barley insurance products. Notice the maximum coverage level for the pea APH is only 0.75, lower than both wheat and barley. However, the base price is set at the expected cash price, which is relatively high compared to the other two crops. A higher base price and a higher coverage level can both increase the indemnity payment. However, a higher coverage level results in a lower premium subsidy rate based on the current regressive subsidy schedule. The higher base price appears to give growers more potential benefit relative to the loss from a reduced coverage level.

When the government program is eliminated, some hedging takes place for wheat. The levels are comparable with what occurred for the intermediate region. The optimum strategy is CRC for wheat, APH for barley and peas, and hedging 17% of the wheat crop.

The scenario with a premium load but no premium subsidy shows a low (essentially, the minimum) level of wheat insurance in the wet region. Because the coverage choice is truncated at 50%, the choice of no insurance by farmers in the dry and intermediate regions may mean their optimum is slightly below 50% in the case of a premium load without subsidy. Comparing the insurance decisions of the three regions, results suggest a 30% loading without subsidy is right at the margin that drives farmers away from participating in the insurance.

Wet region outcomes also suggest results similar to those for the other regions if the insurance coverage level constraints were relaxed. However, peas are now included in the crop mix. When the premium is both loaded and subsidized ("30% Premium Load with Premium Subsidy"), the optimal coverage for peas is consistently at the maximum allowable of 75%. The combined effect of a 30% load and the 55% subsidy for a 75% coverage level is equivalent to a 41.5% subsidy with no load. The premium payment is determined by $(1 + 0.30) * (1 - 0.55) = (1 - 0.415)$, or (1 minus the subsidy rate). If the grower takes the 75% coverage level under this situation, he or she will take a higher than 75% coverage level in the base scenario if allowed. The base scenario has no load but a premium subsidy of 55%, suggesting the 75% coverage level is a binding constraint. However, selection of higher coverage levels is likely dependent on the assumed premium subsidy levels assigned to the higher coverage levels.

Summary and Conclusions

A utility maximization model is used to model risk management behavior for Pacific Northwest non-irrigated crop producers. Three rotational practices commonly used in the PNW are included (winter wheat/summer fallow, winter wheat/spring barley/summer fallow, and winter wheat/spring barley/dry peas). Representative farms for Whitman County, Washington, are used to model risk management behavior. Risk management portfolios that include hedging with wheat futures, yield insurance, revenue insurance (a stylized IP and CRC), government programs, and several selected combinations are analyzed. Equivalent variation is used to rank the alternative portfolios.

Results generally suggest that government programs account for the primary value associated with risk management portfolios available to non-irrigated PNW crop producers. This likely reflects both the price risk protection associated with countercyclical (CC) payments, and the general increase in assured revenue. Contrary to previous studies when the CC program was not in place, hedging or combining hedging with insurance products play a more limited role for increasing risk management value. Portfolios that include hedging with futures are dominant only when government payments are eliminated.

Turvey and Baker (1990) found similar results for an Indiana corn and soybean farm when farm programs were dominated by the loan program and deficiency payments. This result is different, however, relative to Midwest corn/soybean production assessed by Rios and Patrick (2007), where hedging in futures provided greater risk management benefits. The high correlation between corn and soybean cash and futures prices is a clear contrast to what is observed for wheat in the PNW region. Hedging may be less effective for regions outside the Midwest and Plains regions, where cash and futures markets are more closely connected. Perhaps there is a need to provide specific risk management tools for those regions where futures markets tend to be less effective.

A few points need to be highlighted focusing specifically on the paper's three objectives. First, the optimum portfolio is consistently CRC for wheat (the only rotation crop with a CRC program), plus APH for the other available crops. This result is similar to the findings reported for the Midwest region by Rios and Patrick (2007), because of the high subsidy value of crop insurance programs as well as their risk protection value. APH is preferred to IP even when government programs are eliminated as a source of price risk protection. With regard to rotations, there appear to be some diversification impacts for the multiple crop rotations commonly used in the PNW region.

Second, government programs have a high income transfer value and clearly dominate total risk protection. Changes in risk protection value consistently occur in the anticipated direction when the alternative scenarios are implemented. However, the changes are relatively small due to the dominance of government program payments.

When scenario changes impacting the cost of insurance products are analyzed, the sensitivity to premium subsidies and premium loads is apparent but small. When the premium subsidy is eliminated, a 30% load appears prohibitive since all insurance products are either not used, or used at the lowest allowable level (50% in the wet region). When a 30% premium load is assigned with the premium subsidy, or the loading factor is reduced to 1.0 (actuarially fair premium) with the existing premium subsidy structure, insurance products are used but sometimes at slightly lower coverage levels. The lower coverage levels occur when the premium subsidy is in place, suggesting producers adjust coverage to maximize premium subsidy values. Results are similar to work conducted by Turvey (1992) on Canadian insurance programs, where the premium subsidies had a significant impact on risk management portfolio selection.

Additionally, the base price setting procedure appears to have a noticeable impact on crop insurance products. Wheat and pea products have a base price close to their expected price in the PNW. Both products tend to be used at higher levels, and provide greater risk protection value when compared with barley. The base price for barley insurance is lower relative to the expected cash price when compared to wheat and peas. Results generally seem robust relative to the risk preference of decision makers. Increasing the risk-aversion coefficient from 2 to 3 impacts the EV levels slightly, but has no impact on the relative ranking of alternative risk management portfolios.

With regard to the constraints associated with the current maximum coverage levels, their impact on growers' choice and associated welfare likely depends on the associated policy provisions. With no premium load and no subsidy and an actuarially fair premium, risk-averse growers can always benefit from higher coverage by obtaining higher risk protection and higher welfare. If premiums are loaded and not subsidized, lower coverage levels are selected and the current coverage constraints are not binding. Under the current program, the 85% coverage level constraint for wheat and barley appears to be right at the margin. Growers will likely not select higher coverage levels if premium subsidy patterns follow the current regressive scheme. However, the 75% coverage level for peas appears to be restrictive.

This empirical analysis of three different climate zones in the PNW reveals that the risks farmers face can be quite different across regions, and within an individual county. Accordingly, the optimal risk management strategies also differ. One implication is that the current county-based crop insurance programs may want to consider a zone-based program as suggested by Wang (2000). Secondly, the specific result of PNW farmers relying on government programs instead of hedging has broader implications for those production areas that are outside the core grain production areas of the Midwest and Plains regions of the United States.

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Producers' Preferences for Round Number Prices

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Abstract

The purpose of this study was to determine if a preference for round prices exists in the wheat market and how wheat sales react to price movements around whole-dollar amounts. The results show round prices are slightly more prevalent than non-round prices, and transactions increase when price moves above a whole-dollar amount. While such predictable behavior could be exploited by speculators in other markets, the effect is not large enough to merit concern in the market studied here.

Key words: behavioral finance, round prices, threshold prices, wheat

Recent empirical research in behavioral finance indicates that not all prices are viewed as equal. Round prices (prices ending in zero or five) appear to be more common than non-round prices in many financial markets, such as initial public offering markets, stock markets, and foreign exchange markets (Kandel, Sarig, and Wohl, 2001; Harris, 1991; Fischer, 2004). Results of technical analyses suggest trends tend to increase after certain price levels (specifically round prices) are crossed (Osler, 2003; Aggarwal and Lucey, 2005; Park and Irwin, 2007).

While studies have been conducted regarding price clustering at round numbers and its relationship to market trends in financial markets, little has been done to address the possibility of round prices being preferred in agricultural markets. Since a predictable behavior such as price preference could be exploited by other traders, conducting research to determine whether this particular bias exists in markets outside of the financial industry is important.

Our first objective is to determine if a preference for round prices exists within the Oklahoma wheat market. Descriptive statistics are used to test whether round prices have a greater relative frequency than non-round prices. As noted by Christie and Schultz (1994), market makers in stock markets avoid odd-eighth quotes. The authors contend that this tendency increases liquidity costs to investors because it reduces competition. Similarly, Crespi and Sexton (1994, p. 663) report 80% of transactions between feedlots and packers are at whole-dollar prices. They argue that since packers will round bids down to the nearest whole

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dollar, whole-dollar pricing is a form of noncompetitive behavior.

The second related objective is to determine whether sales increase when prices cross a whole-dollar price threshold from below and decrease when crossing from above. This objective is accomplished using a negative binomial regression of the number of market transactions (wheat sales) against indicator variables measuring when price moves above or below a whole-dollar amount.

Theory

The more frequent occurrence of round prices in the Oklahoma wheat market could result either from management practices at the elevator or from producers' preferences. An overview of how elevators determine producer price is needed in order to better understand the possible causes of round price preference in the Oklahoma wheat market. Elevator managers typically determine producer price by subtracting their margin from the market price the elevator receives.

According to elevator managers, the margins they use to calculate producer price are generally based on historical margins and competitor prices and seldom change from year to year, even though elevator managers may adjust the margin if significant changes in transportation costs occur. Elevator managers do not round the price they receive from the market. If rounding already exists in the market prices that elevators receive and elevator managers use round margins, then producer price may be affected. However, elevator managers state they do not usually set the margin at a round number.

Ascioglu, Comerton-Forde, and McInish (2007) contend there are three primary hypotheses for explaining why round number prices are more prevalent: (*a*) the negotiation hypothesis, (*b*) the collusion hypothesis, and (*c*) the attraction hypothesis. Financial market research often identifies lower negotiation costs as one factor attributed to price clustering at round numbers (Harris, 1991; Niederhoffer, 1965). However, since elevator managers tell us that virtually none of the prices we use are negotiated, the negotiation hypothesis should not be relevant here.[1] Collusion of elevators also seems unlikely, leaving us with the attraction hypothesis to explain the higher frequency of round number prices.

Producers are apparently attracted to round numbers when setting prices for sell orders. According to elevator managers, sell orders are a common wheat marketing tool (Smith, 2003). Sell orders are placed by the producer and give the elevator manager permission to sell a given amount of the stored crop when the price reaches a certain level (Osler, 2003). The agreed upon sell price is known as the "target price." Evidence from sell orders in the currency and stock markets indicates target prices are commonly set at round prices (Harris, 1991; Osler, 2003; Fischer, 2004). Elevator managers agree that target prices on sell orders are almost always set at round prices (Smith, 2003). It is also important to note that price targets are included in some undergraduate agricultural economics textbooks (e.g., Purcell and Koontz, 1999) and are advocated by some extension programs.

Some of the past reasons given for the prevalence of round numbers are applicable in explaining why producers might prefer round numbers when selecting target prices. First, individuals are more likely to select round numbers when they are operating in what Butler and Loomes (1988) describe as "a sphere of haziness." Because producers have little or no ability to predict prices

[1] We received data from a third elevator that did include some negotiated prices. The data from this elevator contain considerably more round numbers, but because the negotiated prices are not identified, we did not use the data from this elevator.

(Brorsen and Irwin, 1996), there is a great deal of uncertainty about the best place to set a price target. In the presence of uncertainty, individuals use heuristics (Tversky and Kahneman, 1974) to provide rough approximations (Mitchell, 2001). When making rough approximations, individuals tend to use round numbers, perhaps because they can process the information more quickly. As Mitchell (2001, p. 418) argues, people may select numbers that they believe others will recognize and so they might pick a round number for a target price because it is easier to communicate and perhaps what the elevator operator expects.

The greater number of sales after crossing whole-dollar price points from below is only partly explained by limit prices, as some of the sales occur the next day and a limit order would be exercised on the same day. With retail prices, the ending digits of 0, 5, and 9 are overrepresented (Schindler and Kirby, 1997). Producers presumably sell more often after prices cross whole-dollar thresholds for the same reasons many retail prices end in 9.

Thomas and Morwitz (2005) and Bizer and Schindler (2005) report consumers do sometimes consider only the leftmost digit, arguing it is a simplification that helps consumers classify prices by their leftmost digit. In the case of wheat prices, $4.99/bushel and $5.00/bushel are only a penny apart, but that penny makes the difference between selling four-dollar wheat and selling five-dollar wheat.

Data

Data for this study are derived from two grain elevators located in the northern and central areas of western Oklahoma. The data span nine crop years, from the harvest of 1992 through the harvest of 2000, and contain individual producer transactions of wheat sales at each elevator. Each transaction includes the number of bushels sold, price per bushel, date of transaction, and the number of weeks after harvest that the transaction took place. Harvest is a four-week period, defined to begin on June 1 for the central elevator and June 12 for the northern elevator. For days with no transactions (and thus no selling prices), the closing Gulf bid price and the most recently observed basis were employed for determining the selling price to use in calculating the variables in the negative binomial model.

The northern elevator has multiple locations and is located near some of Oklahoma's best wheat production lands. The central elevator is situated in an area where wheat is less important and producers tend to produce fewer bushels of wheat than at the northern elevator. The northern elevator's buying locations are interspersed with a strong local competitor, whereas the single buying location of the central elevator does not have a strong nearby competitor.

There is little on-farm storage, so most grain is delivered to the elevator at harvest and stored at the local elevator. Thus, producers must choose where to sell, before choosing when to sell. We argue that transactions are the appropriate unit of analysis rather than bushels. The effect of the ending digit or the leftmost digit is expected to affect whether producers sell or not, but should have little impact on how much they sell at a given price. In fact, many producers make only a single transaction each year.

Table 1 provides the descriptive statistics for each elevator. Average price is the nominal average price received by producers over the nine years of data. The average week after harvest is the average week that producers chose to market their wheat for all years. Percent round number prices is the percentage of individual transaction prices that are round numbers (i.e., prices that end in zero). Percent whole-dollar prices is the percentage of individual transaction prices ending in whole-dollar amounts (e.g., $3.00, $4.00, or $5.00).

Table 1. Descriptive Statistics for Each Oklahoma Grain Elevator (1992–2000)

Descriptive Statistics	Central Elevator	Northern Elevator
Average price ($/bu.)	$3.32	$3.38
Average week after harvest	16.2	17.8
Percent round number prices [a]	12.37%	11.65%
Percent whole-dollar prices [b]	1.27%	1.55%
Percent prices ending in a 5 [c]	11.24%	10.02%
Number of transactions	7,083	6,385

[a] The null hypothesis that round number prices are no more likely than any other ending digit is rejected with χ^2 values of 44.6 for the central elevator and 19.0 for the northern elevator, with one degree of freedom.

[b] The null hypothesis that whole-dollar prices are no more likely than other prices is rejected with χ^2 values of 5.2 for the central elevator and 19.5 for the northern elevator, with one degree of freedom.

[c] The null hypothesis that a price ending in 5 was no more likely than any other nonzero ending digit is rejected with the χ^2 value of 18.5 for the central elevator, but is not rejected for the northern elevator with a χ^2 value of 0.31, with one degree of freedom.

Procedures

The procedures include development of descriptive statistics and regression analysis. The descriptive statistics are used to determine if round prices are more prevalent than non-round prices in the Oklahoma wheat market. The regression model assesses whether producers use whole-dollar prices as threshold levels by estimating how the number of daily transactions changes when prices move above or below whole-dollar prices.

Descriptive Statistics

To examine the prevalence of round prices, descriptive statistics are computed and tested following methods such as those employed by Kandel, Sarig, and Wohl (2001) and Osler (2003). First, T_{jd} is computed, where T_{jd} is equal to the total number of transactions for each elevator j that occurred at each last digit d ($d = 0, 1, \ldots, 9$). Then the relative frequency of transactions occurring at each last digit is determined using the following equation:

$$(1)\quad R_{jd} = \frac{T_{jd}}{\sum_d T_{jd}},$$

where R_{jd} is equal to the percentage of the total number of transactions at elevator j at prices ending with the last digit d. The null hypothesis is that round prices are not more prevalent than non-round prices. A chi-squared test is performed to determine whether a significant difference exists between the frequencies occurring at each last digit. The tests consider the following hypotheses: (*a*) all 10 last digits occur with equal frequency, (*b*) zero occurs with the same frequency as any other digit, (*c*) a whole-dollar price occurs with the same frequency as any other last two digits, and (*d*) a last digit of 5 occurs with the same frequency as the other nonzero last digits.

The χ^2 test statistic (Cai and Krishnamoorthy, 2006) is given by:

$$(2)\quad Q = \sum_{m=1}^{M} \frac{(X_m - np_{m0})^2}{np_{m0}} \xrightarrow{d} \chi^2_{M-1},$$

where X_m is total transactions in category m, n is the total number of observations, and p_{m0} is the hypothesized probability for category m.

Regression Model

To run the regression model, the individual data are aggregated by day for each elevator, whereby each observation contains the daily number of transactions, daily price per bushel, date, and number of weeks after harvest. The number of transactions occurring on the ith day in year t (tr_{it}) is assumed to have a negative binomial distribution with conditional mean λ_{it}, which is defined to be a function of the variables of interest:

$$(3)\quad \ln(\lambda_{it}) = \beta_0 + \sum_{k=1}^{8} \beta_{1k} cropy_{kt} + \beta_2 elevator_i + \beta_3 week_{it} + \beta_4 week_{it}^2 + \beta_5 abv_{it} + \beta_6 abv_{i-1,t} + \beta_7 blw_{it} + \beta_8 blw_{i-1,t} + \beta_9 up_{it} + \beta_{10} up_{i-1,t},$$

where i is the day, t is the year, $cropy_{kt}$ are dummy variables for each crop year, $elevator_i$ is a dummy variable for the central elevator, $week_{it}$ is the weeks after harvest when wheat was sold, $abv_{it} = 1$ if today's price moved above a whole-dollar value, $blw_{it} = 1$ if today's price moved below a whole-dollar value, and $up_{it} = 1$ if today's price is higher than yesterday's price; $abv_{i-1,t}$, $blw_{i-1,t}$, and $up_{i-1,t}$ are values lagged one day.

The mean number of transactions was 2.89 with a standard deviation of 3.36. A Poisson model was initially considered, but was rejected using the regression-based test for overdispersion from Greene (2003, p. 743) with a t-value of 17.29. Estimates with Poisson and negative binomial models were similar, except the Poisson model yielded lower standard errors.

The transactions are expected to increase when price moves above a whole-dollar value; therefore, β_5 and β_6 are predicted to be positive. Conversely, transactions are expected to decrease when price moves below a whole-dollar value; thus β_7 and β_8 are hypothesized to be negative. Note that β_5 and β_6 represent the increase in transactions above that on an average day when prices went up, and β_7 and β_8 represent the decrease in transactions below that normally anticipated when prices go down. Oklahoma producers typically sell the majority of their crop at or close to harvest. Therefore, as weeks after harvest increase, fewer transactions are expected, and β_3 is predicted to be negative.

Results

Descriptive Statistics

Figures 1 and 2 present the histograms for the relative frequency of transactions at the two elevators for each possible last digit in price. Zero is the most common ending digit for both elevators, but 5 is the second-most common digit only at the central elevator.

As expected, more transactions take place at prices with a last digit of zero. If prices ending with a zero were not preferred, then only 10% of prices would be expected to end in a zero. The frequency of zero as the last digit in price was 11.65% for the northern elevator (Figure 1) and 12.37% for the central elevator (Figure 2), revealing a preference for round numbers, but not a large preference.

For the chi-squared equal proportion test, the null hypothesis that the frequency of transactions is equally distributed across all last digits was rejected at both elevator locations. The calculated χ^2 statistic (with 9 degrees of freedom) was 126.8 for the central elevator and 51.7 for the northern elevator. The chi-squared tests also provide strong evidence that prices ending in zero and whole-dollar amounts are favored by producers (Table 1). Digits ending in a 5 are significantly more common than other nonzero ending digits at the central elevator, but not at the northern elevator.

As anticipated, the results indicate the existence of a preference for round prices in the Oklahoma wheat market. However, the preference found in this study is small compared to findings reported in studies of financial markets (e.g., Niederhoffer, 1965). The results are consistent with a small number of sell orders being placed at round prices, which then leads to the prevalence of round prices in the wheat market.

Thus, the results are also consistent with the attraction hypothesis, which states that producers are attracted to round prices when selecting target prices for sell orders. The relatively small preference for round numbers relative to other markets is explained in part by the pricing system, which involves no negotiation or auction. But, it also reflects that only whole-cent prices are used. Wheat futures prices are quoted in quarter cents, so in a sense the cash prices are already rounded.

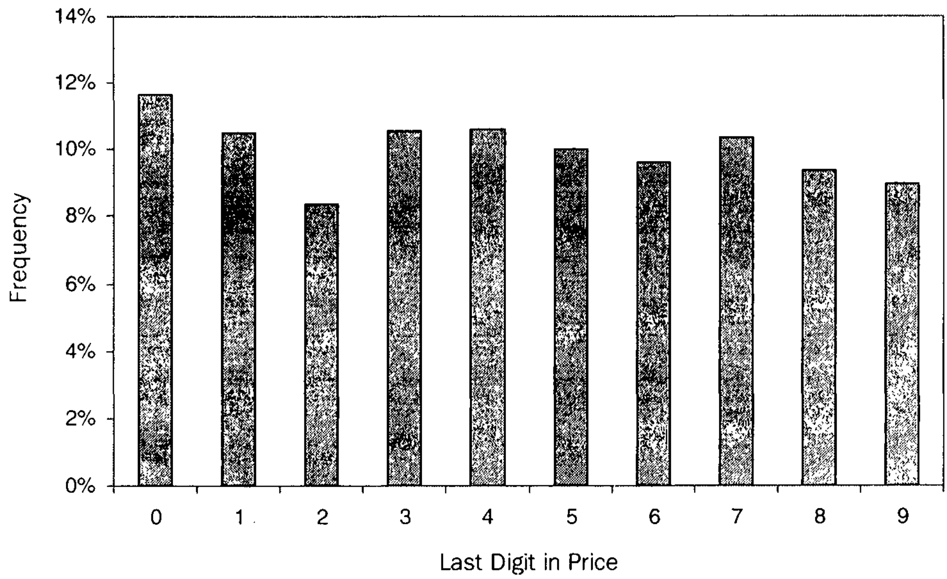

Figure 1. Histogram of Last Digit in Price for Northern Elevator

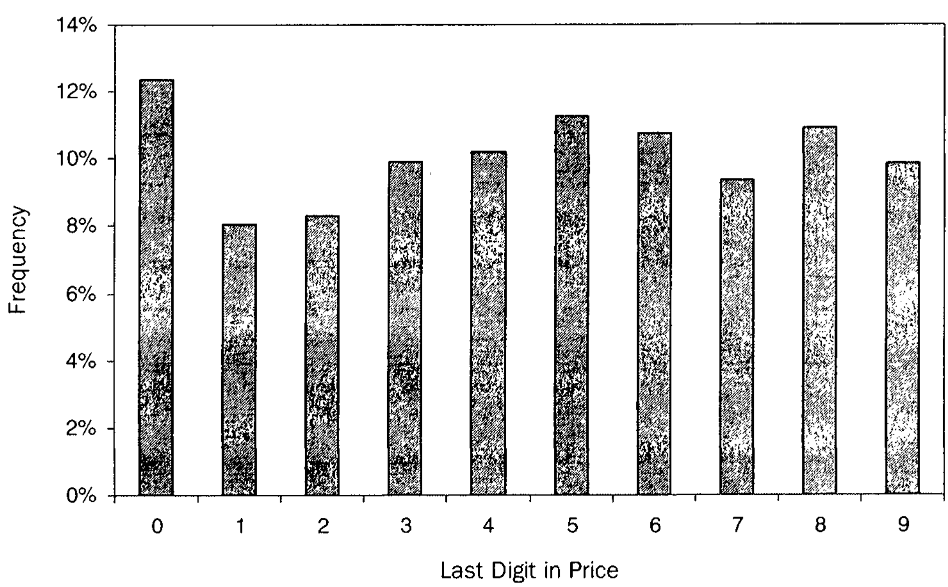

Figure 2. Histogram of Last Digit in Price for Central Elevator

Table 2. Negative Binomial Regression of Number of Transactions and the Direction of Price Movement

Variable	Estimate	χ^2	Pr > χ^2	Effect [a]
Intercept	1.247	399.66	< 0.0001	7.1
1993 crop year	0.0912	1.96	0.16	0.27
1994 crop year	-0.068	1.06	0.302	-0.18
1995 crop year	0.275	18.59	< 0.0001	0.91
1996 crop year	0.195	9.05	0.0026	0.62
1997 crop year	0.084	1.87	0.171	0.25
1998 crop year	0.396	26.11	< 0.0001	1.40
1999 crop year	0.094	2.04	0.15	0.28
2000 crop year	0.319	24.46	< 0.0001	1.08
Central elevator	0.0157	0.24	0.6217	0.04
Weeks after harvest (*week*)	-0.029	58.50	< 0.0001	
Weeks after harvest squared ($week^2$)	0.005	0.33	0.564	
Move above whole-dollar price (*abv*)	0.367	13.40	< 0.0003	1.28
Lagged move above whole-dollar price (abv_{t-1})	0.490	27.09	< 0.0001	1.82
Move below whole-dollar price (*blw*)	-0.348	10.19	0.0014	-0.84
Lagged move below whole-dollar price (blw_{t-1})	-0.027	0.06	0.79	-0.07
Price move upward (up_{it})	0.228	53.80	< 0.0001	0.74
Lagged price move upward ($up_{t-1,t}$)	0.197	39.72	< 0.0001	0.62
Dispersion	0.6039			

Notes: The regression is based on 4,406 daily observations. Descriptive statistics showed that daily average prices moved above a whole-dollar amount on 2.6% of the observations, and also moved below a whole-dollar amount 2.6% of the time. The average number of transactions per day ($\bar{\lambda}$) was 2.89.

[a] The effect is the difference in number of transactions when the indicator variable is one and when it is zero. The formula used is $[\exp(\hat{\beta}_i) - 1] \times \bar{\lambda}$, where $\bar{\lambda} = 2.89$.

The Regression Model

The results of the negative binomial regression of number of transactions with respect to price movement above or below a whole-dollar amount are reported in Table 2. The results of the regression analysis show that the coefficients for the movement of price above a whole-dollar amount and for the lagged movement of price above a whole-dollar amount exhibit the expected positive sign, and both are significant.

As shown by the values in the last column of Table 2, as price moves above a whole-dollar amount, there are 1.28 more transactions above the number of transactions expected on an up day. For example, if price increases from \$2.88 to \$3.02, it would cross the \$3.00 threshold and producers would increase their wheat sales (i.e., more transactions would occur). Since the average for the data set is 2.89 transactions per day, the effect of crossing a whole-dollar threshold is large. The effect is stronger for lagged prices than current prices, which confirms the left-digit effect is not due entirely to sell orders since sell orders should be executed when the threshold is first crossed.

The coefficients for the movement of price below a whole-dollar amount and for the lagged movement of price below a whole-dollar amount are both negative, but the lagged variable is not significantly different from zero at the 95% confidence level. The positive coefficients for all up price movements suggest that producers are negative feedback traders, which corroborates the findings of Anderson and Brorsen (2005).

The regression results support the conclusion that Oklahoma wheat producers place extra importance on the leftmost digit, similar to the findings of Bizer and Schindler (2005) for retail consumers. Unlike the ending digit effect, the effect of the left-most digit is relatively large. It is difficult to envision, however, any trading strategy that would profit based on producers' actions in these decentralized markets, because the price will typically cross the whole-dollar threshold on different days in different locations. In centralized markets, like futures markets, this same behavior would cause clustering that would result in resistance and support price thresholds. Producers should be advised to avoid whole number prices when submitting limit and stop orders in futures markets.

Conclusion

Round prices are slightly more common than other prices at the two Oklahoma wheat elevators in the market studied here. This finding is likely due to producers using sell orders with a majority of the target prices set at round numbers.

Regression analysis was used to determine the effect of movements around whole-dollar price thresholds on wheat sales. The test showed that wheat sales increased when prices moved above a whole-dollar amount, and sales decreased when prices moved below a whole-dollar amount. These results reveal that producers place extra weight on the leftmost digit, which is sometimes denoted "ending digit dropoff."

There does not appear to be much potential in these specific markets for speculators to profit from producers' preferences for round number prices. Because of differences in transportation costs, prices will not cross the whole-dollar threshold at the same time across different locations. Transaction costs are likely too high for speculators to take advantage of producers in cash wheat markets. However, to the extent that this same behavior takes place in other markets, such as futures markets, there is a potential for speculators to profit from producer preferences for round number prices and producers placing extra weight on the leftmost digit.

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Announcement of The W.I. Myers Prize in Agricultural Finance

To encourage the publication of peer-reviewed research, Myers Endowment funds will be used to support two awards starting with the Spring 2006 issue of ***Agricultural Finance Review***. The prizes will include a monetary award as well as a certificate. Selected by the editors and on nomination by subscribers to *AFR*, the two awards will be for:

- *Overall Best Journal Article*, and
- *Best Journal Article Authored by a Student.*

All articles are eligible for an award, including invited papers and papers submitted for special issues. There are no specific criteria for determining what constitutes a "best" journal article except that it will be known to be best once read. The student award must have the student as senior author, must have been written principally by the student, and must contain thesis, dissertation, or any other research originated by the student either independently or under the advisement of a faculty. The two awards are mutually exclusive, meaning that if the student award is also the best journal article, only the best journal article award will be given. The winners of the award will be announced annually in the Spring issue of ***Agricultural Finance Review.***

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Calum G. Turvey
W.I. Myers Professor of Agricultural Finance
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