Staff Papers Series

Staff Paper P90-19 March 1990

Volume II

First Annual Conference on

AGRICULTURAL POLICY AND THE ENVIRONMENT

Proceedings of a Conference Sponsored by

University of Minnesota
Center for International Food and Agricultural Policy

Agricultural Development Regional Agency (ESAV)

University of Padova

Motta di Livenza, Italy
June 19-23, 1989

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture, Forestry and Home Economics
St. Paul, Minnesota 55108

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FORWARD

The papers in this volume are the result of the First Annual Conference on Agricultural Policy and the Environment, held at Motta Di Livenza, Italy, June 19-23, 1989. This conference resulted from the collaboration of the University of Padova, University of Minnesota and the Ente di Sviluppo Agricolo (the Veneto Regional Development Authority) which provided the lovely setting for the conference. The University of Minnesota Center for International Food and Agricultural Policy has entered into a long-term agreement with these Italian counterpart institutions to study problems of land use, land values, agricultural production and their impact on environmental quality. In both countries, the agriculture/ environment linkage is of growing importance.

The conference proceedings are divided into four volumes, according to the sessions presented.

In the fall of 1990, the Second Annual Conference on Agricultural Policy and the Environment will be held in Minnesota. We look forward to repaying the warmth and hospitality of our Italian counterparts. We would especially like to thank Danilo Agostini, Guisseppe Stellin, Cesare Dosi and the entire staff of the ESAV research station in Molta di Livenza, Veneto, and Judy Berdahl for her typing and editorial assistance.

C. Ford Runge, Director
Center for International Food and
Agricultural Policy

Some Lessons From Land Price Booms and Busts*

Philip M. Raup**

I. Introduction

I am inviting you to visit with me what one writer has called that darkest of dark ages, the day before yesterday. We have just passed through one of the most severe periods of boom and bust in farmland prices in our history. We are still too close to the experience to permit a balanced interpretation of what happened, and why. But it does seem appropriate to distill some tentative lessons from these traumatic events, and ask ourselves what we have learned that may be useful in the future. The discussion to follow will focus on the Midwest since that is the region in which the amplitude of the boom and bust was greatest, and it is also the region for which historical data are most reliable.

II. A Brief Look at the Scale of the Boom and the Bust

The differential magnitudes of the boom phase from 1972 to 1981 in The Corn Belt, Lake States, and Northern Plains are shown in Table 1. In this period farmland values increased approximately five-fold in Minnesota and Iowa, and four-fold or more in all of the other leading Corn Belt states. The smaller increases were in Missouri, Kansas, South Dakota, and Michigan.

In the bust phase, which ran from 1981 to 1987 in all Corn Belt and Lake States, the collapse of values was an approximate reverse image of

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*A condensation of papers presented at a University of Minnesota-University of Padova Workshop on Agricultural Policy and the Environment, Motta di Livenza, Italy, June 20, 1989, and at the National Agricultural Credit Conference, Chicago, Illinois, September 18, 1989.

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Table 1

Percentage Increase in Value Per Acre of Farm Land and Buildings March 1, 1972 to Peak, February 1, 1981 in U.S. Corn Belt, Northern Plains and Lake States[a]

State	Average Value Per Acre, Land and Buildings 1972	Average Value Per Acre, Land and Buildings Peak in 1981 or 1982	Percent Increase Peak/1972
	Dollars		Percent
Minnesota	241	1,281	531.5
Iowa	414	1,999	482.8
Indiana	435	2,031	466.9
North Dakota	98	455[b]	464.3
Nebraska	170	730[b]	429.4
Wisconsin	274	1,152	420.4
Illinois	522	2,188	419.2
Ohio	439	1,831	417.1
South Dakota	87	349[b]	401.1
Missouri	261	990	379.3
Kansas	174	628[b]	360.9
Michigan	370	1,289	348.4

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a U.S. Dept. of Agriculture, ERS, Farm Real Estate Market Developments, CD-83, July 1978, and Agricultural Resources, Agricultural Land Values and Markets, Situation and Outlook Report, AR-6, July 1987, p. 8.

b Peak values were in 1981 for all Corn Belt and Lake States, but 1982 for all Northern Plains States, (N. Dakota, S. Dakota, Nebraska, Kansas).

the boom, as shown in Table 2. The greatest declines were in Iowa and Minnesota, where over sixty percent of peak values were wiped out. In the remaining Corn Belt states the wipe-out was fifty percent or more. In general, the greatest increases in the boom and the greatest declines in the bust occurred in regions with the most productive agricultural land.

The land price boom and bust from 1972 to 1987 was a prime-land phenomenon. This sets it apart from other boom-and-bust periods in the history of farmland price movements in the United States. Our traditional farmland price cycles up to the second World War had been triggered by expansion into marginal or newly-settled lands. This was a minor aspect of the 1972-87 period. In this sense it can be considered a misreading of profit potentials at the intensive margins of agricultural land use, rather than at the extensive margins. Our most recent cycle in farmland prices involved primarily the rich, rather than the poor. This can be read as one measure of the extent to which American agriculture has fully matured.

III. Sources of Demand During the Boom

The principal demand for land in the recent boom involved not only the better lands but also the nearest neighbors. Nationally, and at the peak of the boom, farm owner-operators were buying two-thirds of the acres sold, tenants ten to twelve percent, and non-farmers approximately one-fourth. In the Lake States, Corn Belt, and Northern Plains, owner-operators bought two-thirds to three-fourths of the area transferred, and non-farmers ten to twenty percent. The predominant demand for land in the areas that experienced the greatest price increases came from neighboring

Table 2

Relative Decline in Average Value of Farm Land Per Acre From Peak to 1987 in U.S. Corn Belt, Northern Plains and Lake States[a]

State	Price Per Acre: Average at Peak[b]	Price Per Acre: Average 1987	1987/ Peak	Percent of Peak Value Lost to 1987
	Dollars Per Acre		%	%
Iowa	1,999	748	37.4	62.6
Minnesota	1,281	493	38.5	61.5
Indiana	2,031	931	45.8	54.2
Nebraska	730	335	45.9	54.1
Illinois	2,188	1,040	47.5	52.5
South Dakota	349	178	51.0	49.0
Ohio	1,831	942	51.4	48.6
Kansas	628	340	54.1	45.9
Wisconsin	1,152	626	54.3	45.7
Missouri	990	552	55.8	44.2
North Dakota	455	282	62.0	38.0
Michigan	1,289	833	64.6	35.4

[a] U.S. Dept. of Agriculture, Economic Research Service, Agricultural Resources, Agricultural Land Values and Markets, Situation and Outlook Report, AR-6, July 1987, p. 8.

[b] Peak values were in 1981 for all Corn Belt and Lake States, but 1982 for all Northern Plains States, (N. Dakota, S. Dakota, Nebraska, Kansas).

farmers, expanding the size of their operations. In this sense the 1970's land-price boom in the Midwest was home-grown (USDA, 1984).

Data for Minnesota provide the clearest evidence of this trend to market dominance by farm expansion buyers. Figure 1 shows the distribution of farmland purchases from 1954 to 1988 among three classes of buyers: Those buying to expand an existing operation, those taking over intact farm units as operating buyers, and investors who were neither expansion buyers nor did they intend to be operators. By the end of the boom farm expansion buyers accounted for 75 to 80 percent of all farm sales statewide. In the south central Corn Belt counties, where land price increases had been most extreme, the figure approached 90 percent. In these same counties, from 80 to 90 percent of all buyers lived within 10 miles of the tracts purchased (Smith and Raup, 1983).

While comparable data are not available for other Midwestern states, it seems reasonable to conclude that the driving force in the land boom after 1972 was a search for economies of size by neighboring farmers. In this search they were apparently driven by a belief in ever-expanding markets for farm products. What accounted for this belief?

IV. Understanding the Origins of the Land Boom

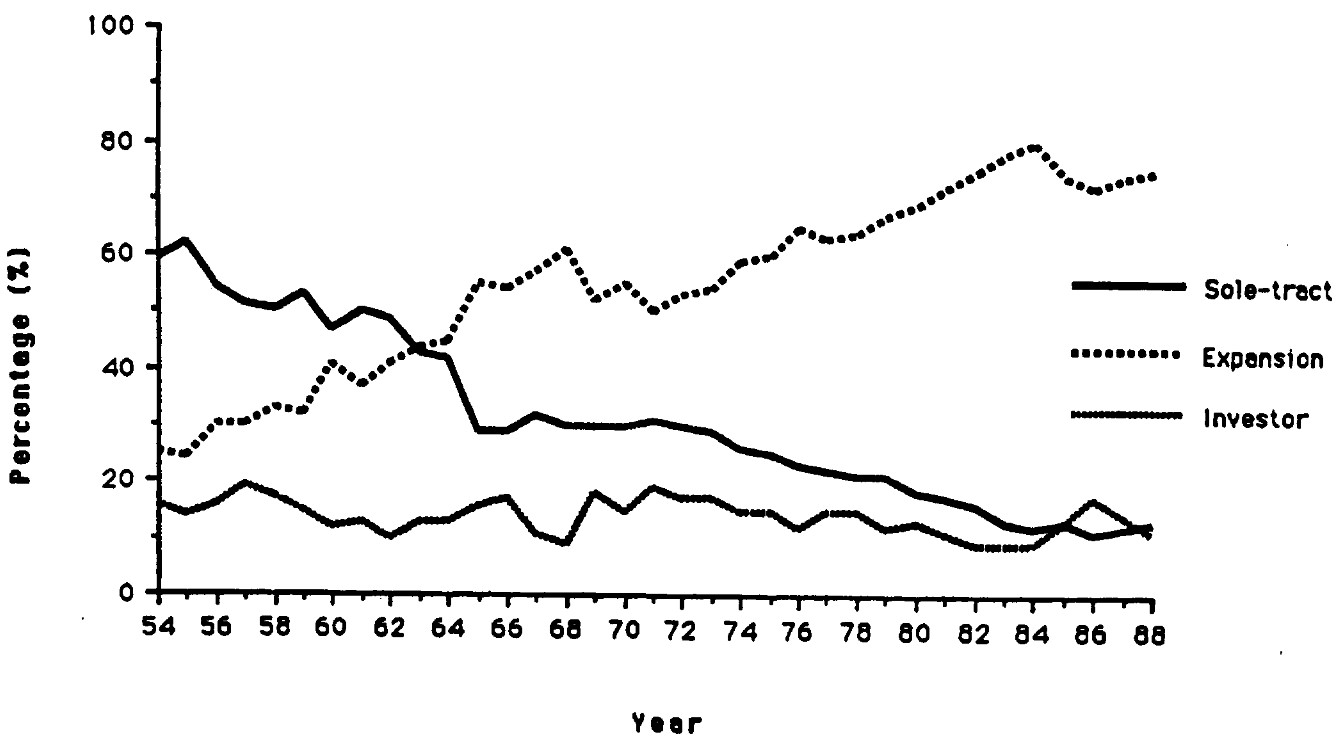
The early years of the 1970's mark a hinge-point in our perception of food-supply and environmental problems in a world-wide dimension. Three events in 1972 and 1973 dramatized this shift:

a.) The unexpected appearance of the Soviet Union in the world grain market as a major importer.

b.) The formation of OPEC and its subsequent embargo of petroleum sales to the U.S. and other nations.

Figure 1

Percentage of Farm Sales by Type of Buyer, Minnesota, 1954-1988



Source: Schwab and Raup, 1989.

c.) The publication of the book "The Limits to Growth" (Meadows, et al, 1972) and the resultant wide publicity given to the presumption of physical supply constraints on further resource use.

The catalyzing effect of these events occurred in a setting created by a world-wide concern with the consequences of explosive population growth. The rhetoric of the era was apocalyptic. Paul Ehrlich popularized the notion of a "Population Bomb," waiting to explode, and concluded in the late 1960's that "it is already too late to prevent a drastic rise in the death rate through starvation" (Ehrlich, 1968, p. 3). Garrett Hardin wrote of the "Tragedy of the Commons", concluding that freedom to breed is intolerable and that we must recognize "the necessity of abandoning the commons in breeding" (Hardin, 1979, p. 1248). Kenneth Boulding wrote in space-age metaphor of the limits imposed by "spaceship earth", providing those concerned with land resources with one of their most evocative symbols (Boulding, 1966).

The central premise of the concern with resource limits lies in what can be called the "finite assumption". The notion that the earth's supply of all resources is fixed seems so self-evident that it can be asserted with no proof needed. Yet it is this finite assumption that must be questioned.

In terms of the measurements used to estimate resource supply, there can be no resources until they are recognized by human beings. Quantity cannot be measured except in terms of the use to which the resource can be put. These uses, in turn, are functions of perception, rates of recovery, costs of transport, efficiency in conversion, prices, and consumer tastes. These change, and the available stock of resources changes with them.

A stock of resources is thus inadequately measured in terms of physical quantities. In economic terms, the stock does not exist until it can be used by human beings. A resource, in this view, is a cultural achievement, for which the proper measurement units can only be defined in terms of our intelligence and skill in putting resources to use. At any one time, intelligence and skills are limited. But the history of the human race provides no evidence that they are fixed or finite over time. If resources can only be defined in terms of human intelligence, and if this is not finite, then the stock of resources cannot be finite.

This is the lesson that was forgotten or rejected in the build-up to the land-boom of the 1970's. The participants in that boom may never have heard Will Rogers dispense his famous advice to "buy land, they ain't making it any more", but they acted on that belief. Overriding any calculations of tangible profits from land appreciation or economies of size was a profound belief that the world was running out of land. Relearning the lesson that economic land is made, not discovered, and that its supply is not properly measured in acres, is perhaps the most important lesson taught by the recent land boom and bust.

V. Fueling the Boom

A belief in the ultimate wisdom of buying farm land was not confined to farmers, it infused their creditors as well. Almost by definition, booms in any market run on credit and the land boom of the 1970's was no exception. Throughout the life of the boom credit was never a constraint. Instead, it fueled the boom.

Until well into the 1960's credit-financed farmland transfers rarely exceeded 60 percent of all transfers for the US as a whole, and the ratio of debt to purchase price was typically under two-thirds. Both of these ratios rose in the late 1960's, and reached unprecedented levels in the 1970's. By the end of the boom, credit-financed transfers accounted for 93 to 95 percent of all transfers in the Corn Belt, Lake States, and Northern Plains, and ratios of debt to purchase price ranged in these three regions from 79 to 83 percent (USDA, 1984, pp. 26, 28). Land market-related debt on this scale had never before been recorded in the United States. In this dimension the farmland boom of the 1970's was unique in U.S. history. It reflected an intense drive for market share by farmland creditors, and especially by the Federal land Banks.

Total outstanding farm real estate debt as of January 1 (excluding real estate debt held by farm households) increased 3.9 times from 1970 to the peak in 1984-1985. In that same period farm real estate debt held by Federal Land Banks increased 7.4 times, that held by the Farmers Home Administration 4.5 times, by banks 3.0 times, by individuals and others 2.8 times, and by life insurance companies 2.2 times (Federal Reserve Bank, Dec. 1984). The major shift in market shares was to the Federal Land Banks, and in smaller degree to the Farmers Home Administration. The greatest proportionate losses in market shares were by life insurance companies, individuals and others, and commercial banks, in that order, as shown in Table 3.

The dominant position of the Federal Land Banks in farm real estate mortgage lending was one of the most distinctive characteristics of the land boom of the 1970's. For twenty years, from 1948 through 1967, life insurance companies had held the predominant share of farm real estate

Table 3: **Shifts in Market Share of Outstanding Real Estate Debt of Farm Businesses as of January 1, 1970 and 1985 (excluding Real Estate Debt of Farm Households)**

	1970		1985	
Lender Category	**Debt in Millions of Dollars**	**Percent of Total**	**Debt in Millions of Dollars**	**Percent of Total**
Total Real Estate Debt of Farm Businesses	**26,246**	**100.0**	**102,000**	**100.0**
Distribution by Type of Lender				
Federal Land Banks	**5,977**	**22.8**	**44,300**	**43.4**
Farmers Home Adm.	**2,029**	**7.7**	**9,100**	**8.9**
FLB plus FmHA	**8,006**	**30.5**	**53,400**	**52.3**
Banks	**3,116**	**11.9**	**9,400**	**9.2**
Life Insurance Co.	**5,222**	**19.9**	**11,700**	**11.5**
Individuals and Others	**9,902**	**37.8**	**27,500**	**27.0**

Agricultural Finance Data Book, Research Division, Federal Reserve Bank, Washington, D.C., December 1984, p. 21. Debt peaked nationally at $102,821 million in 1984, but somewhat later in many of the major farming regions.

debt. They were overtaken by the Land Banks in 1968, at first slowly and then with a rush after 1970. In the twenty years from 1966 through 1985, the Land Banks increased their market share in every year except 1984, from 20.0 percent in 1966 to 43.4 percent in 1985.

The pattern of shifts among other debt holders shows interesting variations. The share of outstanding debt held by commercial banks was remarkably constant at 12 to 13 percent throughout the 1960's and 1970's. Their share of total farm business real estate debt in 1979 was almost exactly the same as in 1970. It declined briefly in 1980-83 and then began a rise that is still continuing.

In contrast, life insurance companies lost market share in every year from 1966 through 1985 except in 1978 and 1979. This suggests that the less aggressive policies of life insurance companies in farm real estate lending in the early years of the land boom were reversed in the mid-1970's. They undoubtedly found themselves at the end of the boom with a disproportionate number of mortgages written late in the boom at the high end of the cycle in land prices and interest rates.

This leads to some reflections on the methods used by creditors in valuing farmland. A now-conventional approach is to use a bid-price model, in which the traditional capitalization formula is modified to take expectations of future trends in revenues and interest rates into account. This encounters difficulties in periods of rapid inflation.

A change in the expected real rate of inflation does not lead to an increase in land values, if interest rates are free to adjust to take the expected rate of inflation into account. The increase in the expected rate of inflation will be approximately canceled out by the rise in the expected nominal rate of interest, leaving the real rate of interest unchanged. But what happens if the expected real rates of interest turn negative?

In theory, this is not supposed to happen. In a fully functioning capital market nominal interest rates are presumed to adjust to expectations of inflation rapidly enough to maintain a positive real rate of return to capital.

In fact, negative real rates of interest do occur. Real rates of interest on Federal Land Bank farm mortgage loans were negative in 18 of the 32 quarters from 1973 through 1981.

If the expected rate of inflation is large enough and persistent enough to lead to expectations that the real rate of interest will become negative, then capital will have no cost. The bid-price model breaks down. Dividing an expected positive real rate of return to farm assets (land) by an expected negative real rate of interest leads to a nonsense result.

If there are differentials in the speed with which nominal interest rates adjust to expectations of inflation in various sectors of the economy, then the effects of inflation will be most pronounced in those sectors that are slowest to adjust. In the U.S., the farm mortgage loan sector has been especially slow to adjust nominal rates of interest when confronting inflation. This increased the attractiveness of the use of credit to purchase farm land in the 1970's, thus providing one of the best ways to benefit from the tendency for nominal interest rates to lag behind the market in a period of rising inflation.

A key lesson taught by the land boom of the 1970's is that the FLB, the insurance companies, and other lenders fed inflationary tendencies by failing to raise interest rates fast enough and high enough to maintain a positive real rate of return on capital. Market share can be achieved at a price that is too high.

One additional lesson taught by the land boom is a new appreciation of the power of anticipated capital gains, in nominal dollars, to blind people to the trends in real income, measured in deflated dollars. This is illustrated in Figures 2 and 3.

In corn-soybean counties of southwestern Minnesota real cash farm income per crop acre peaked in 1974 and fell almost continuously to 1984. In contrast, real land values per acre peaked in 1979, five years after the peak in real cash income per crop acre.

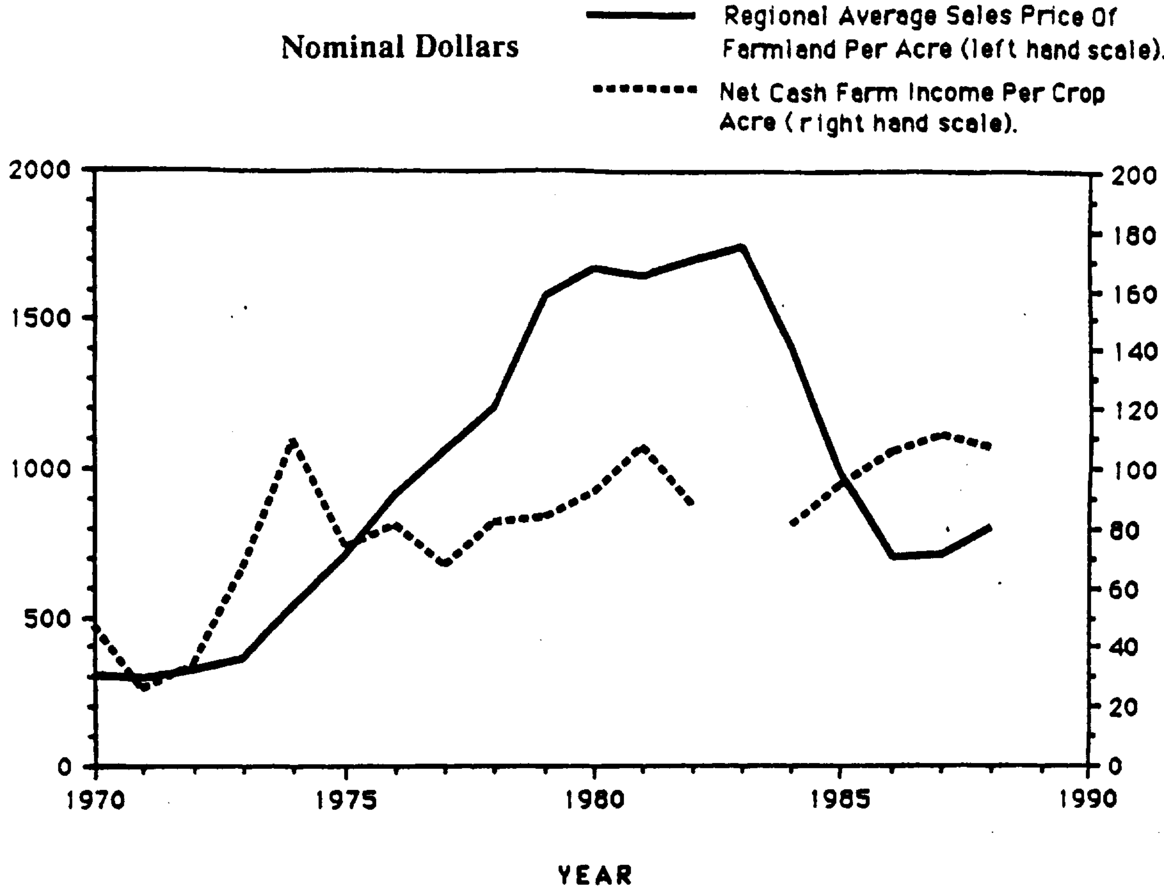
In nominal dollars, cash income per crop acre peaked in 1974 and fluctuated thereafter in a rather narrow range of between approximately $80 and $110 per crop acre throughout the fifteen years from 1974 through 1988. During the land boom period, which in southwestern Minnesota lasted from 1972 to 1983, both nominal and real cash income per crop acre rose only in the first three years, 1972-1974. In the years of greatest land boom activity, the trend in nominal cash income per crop acre was essentially flat and the trend in real income was falling sharply.

One tentative conclusion is that, except for the first three years, those valuing land for purchase or for credit were capitalizing expected future capital gains into bid prices or appraisals.

A second tentative conclusion is that conventional approaches to land valuation are irrelevant in a period of growing inflation. Psychological considerations take command, and the boom feeds on itself. In the absence of sharp credit rationing, the interest rate loses its power to guide

Figure 2

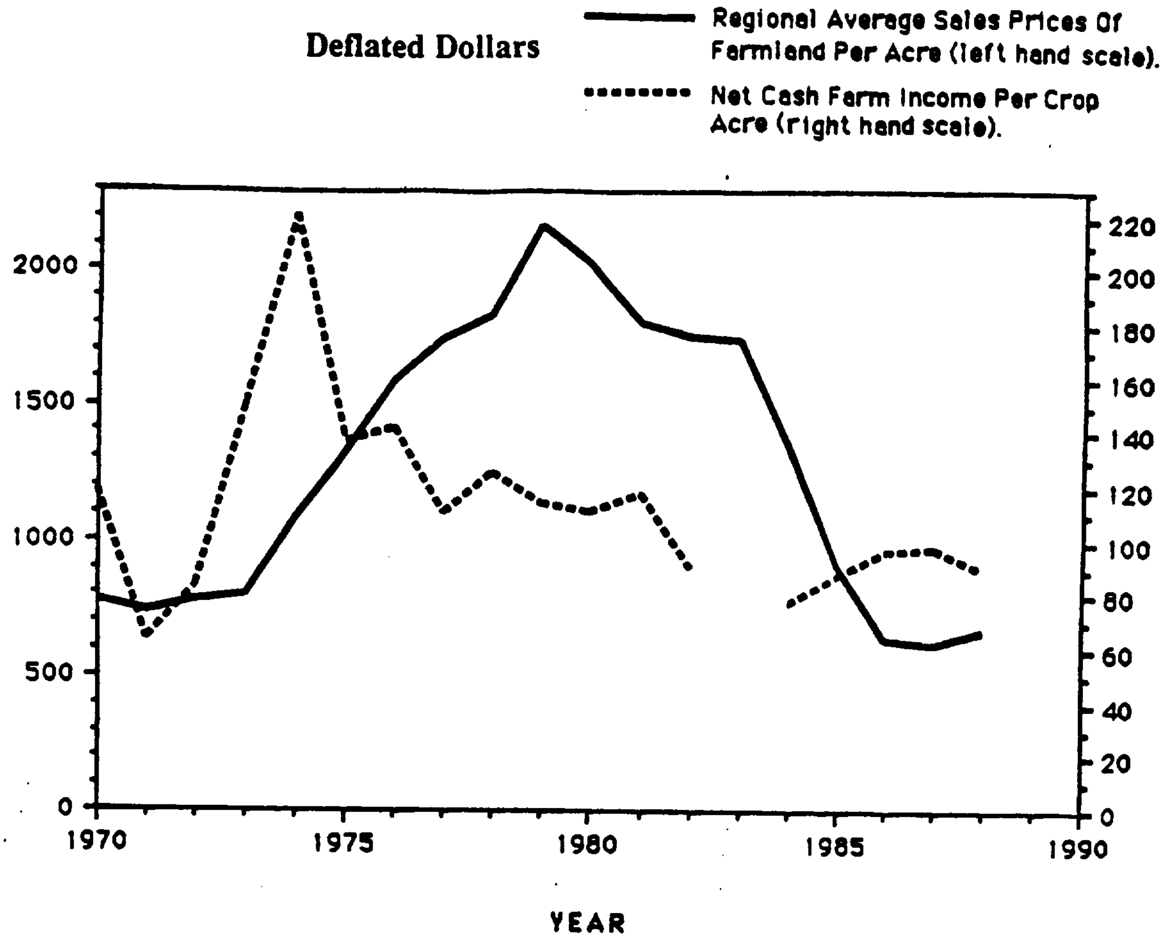
Trends in Land Prices per Acre[a] and Net Cash Farm Income per Crop Acre[b], Southwestern Minnesota, 1970-1988



[a]Annual University of Minnesota Survey of the Rural Real Estate Market (Economic Development Region 8).
[b]Annual report of the S.W. Minnesota Farm Business Management Association; 1983 data being revised.

Figure 3

Trends in Land Prices per Acre[a] and Net Cash Farm Income per Crop Acre[b] (Deflated by (CPI, 1982-84), Southwestern Minnesota, 1970-1988



[a]Annual University of Minnesota Survey of the Rural Real Estate Market (Economic Development Region 8).
[b]Annual report of the S.W. Minnesota Farm Business Management Association

investment decisions. In one often-quoted phrase, "credit loses its guardian." This characterized the boom in farmland prices in the 1970's.

VI. A Concluding Reflection on the Growing Linkage Between the Markets for Farmland and Housing

The major trend in land use in the United States since the Second World War has been the expansion of non-farm residences into formerly rural areas. The rural non-farm population now outnumbers the rural farm population in all but a few of the counties that have in the past been classified as agricultural. This is true of all counties in the Lake States, and of virtually all counties in the Corn Belt. One result has been to superimpose urban and residential concepts of land values on top of land values deemed justified by agricultural use.

The farmland market is being penetrated by the housing market, unevenly but on a massive scale. This introduces housing market risk into areas that in the past had valued land in terms of agricultural risk only. The significance of this added risk element is intensified by the fact that, with the exception of New England and the "Rust Belt" areas around the Great Lakes, the market for housing land has been relatively stable to buoyant for the past 50 years. Nothing comparable in scale to the collapse of farmland values from 1981 to 1987 has occurred in the suburban and rural non-farm housing market.

This may be about to change, for demographic reasons. Housing market studies show clearly that the demand side of the market is driven by individuals in the age group of 25 through 34. The overwhelming majority of first homes are acquired in this 10-year period in the life cycle.

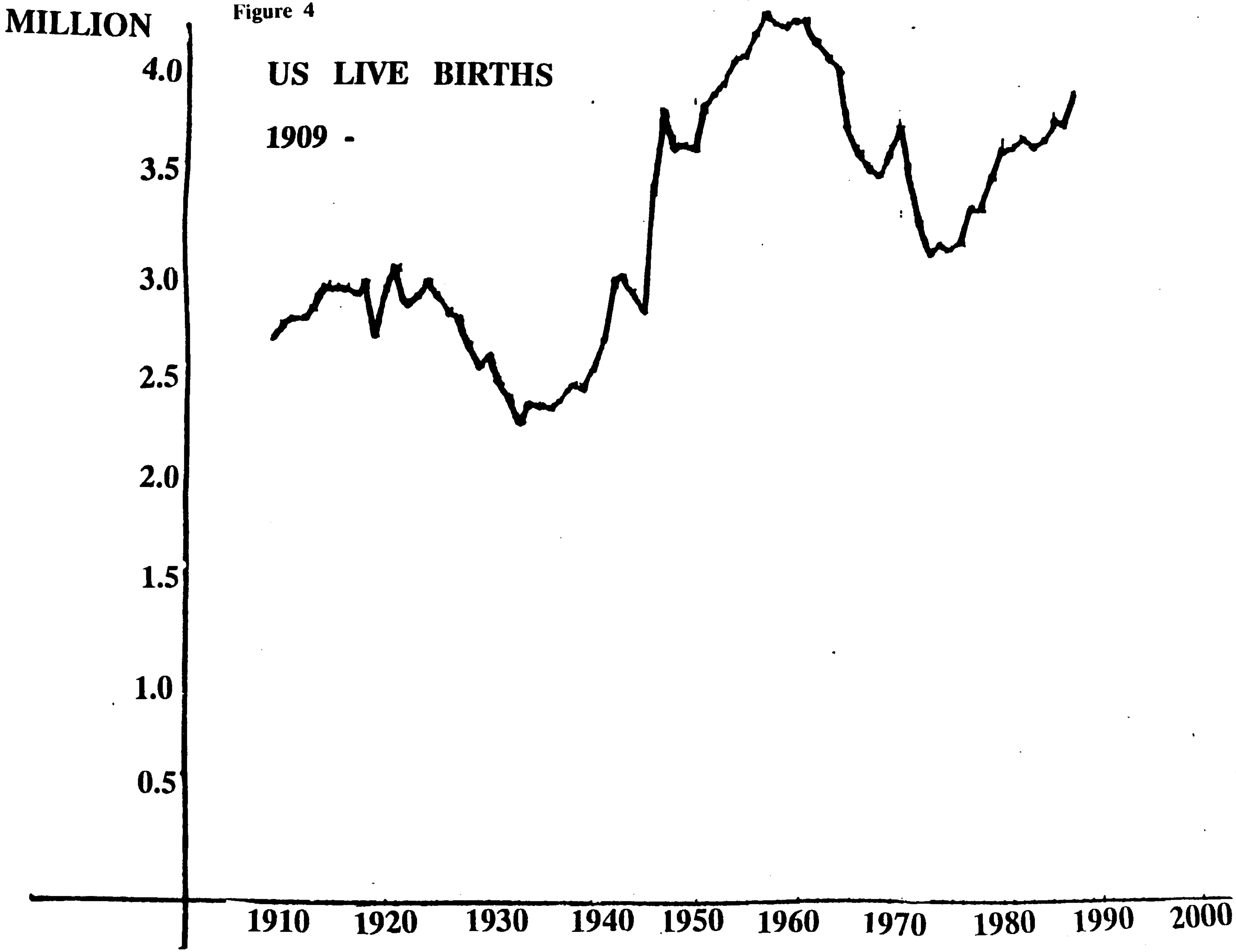
The post-war baby boom in the United States led to an increase in annual births of 50 percent from 1945 to the peak in 1957, and held births above 4.0 million annually for eleven years, from 1954 through 1964. The decline was almost equally dramatic, from an annual peak of 4.3 million births in 1957 to a low of 3.1 million in 1973. The trends are shown in Figure 4.

The effect on housing demand has been unprecedented. Adding 25 years to the figures on annual births, as is done in Figure 5, shows that the boom in farm land prices from 1972 to 1981 coincided almost exactly with the period of maximum increase in the population reaching "housing ages." From 1960 to 1982 the age groups that contributed most heavily to housing demand had increased in almost every year. The annual increment remained near or above 4.0 million from 1973 to 1989, but will fall sharply to a low of just over 3.0 million in 1998.

In the next ten years the annual population of first-home buyers will fall by about one-fourth. This introduces the prospect of a glut in "starter homes" and a reduction in overall housing demand on a scale that we have never before experienced.

While the collapse of farmland prices after 1981 had only minimal impact on the demand for housing land, and may even have increased it, this relationship is not symmetrical. The prospect of downward pressure on farmland prices due to a collapsing housing market is very real. The authors of a recent study of the prospective housing market for the National Bureau of Economic Research concluded that "housing demand will grow more slowly in the 1990's than in any time in the past forty years" (Mankiw and Weil, 1988). We have no data to enable us to estimate the

Figure 4


MILLION
US LIVE BIRTHS
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3.0
2.5
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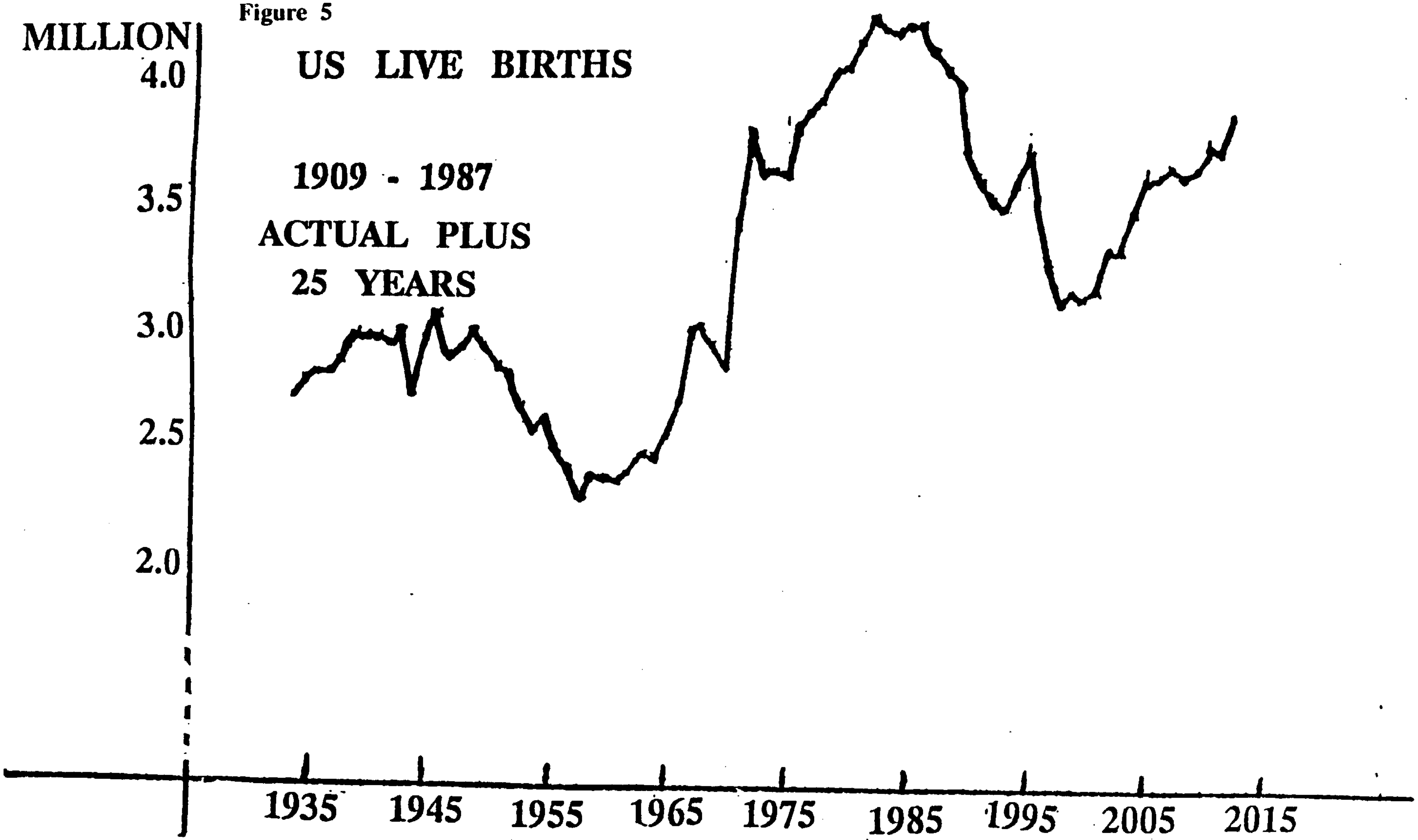
Figure 5



MILLION
4.0
3.5
3.0
2.5
2.0
US LIVE BIRTHS
1909 - 1987
ACTUAL PLUS
25 YEARS
1935
1945
1955
1965
1975
1985
1995
2005
2015

effect on the farmland market, but it is certain to be great, and especially in the eastern Corn Belt and Lake States. While the collapse of the boom in farmland prices in the 1980s did not drag down the housing market, there is a strong prospect that the housing market will contribute a major element of variability to the farmland market in the Midwest for the remainder of this century.

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LAND VALUES AND FARM INCOMES IN MINNESOTA

by Kent D. Olson and Michael D. Boehlje

November 1989

ABSTRACT: Previous research on the land market is reviewed, including econometric models, single-equation models, capital budgeting, other models such as the capital asset pricing model (CAPM), and recent testing of the present value model of land valuation. Land values in Southern Minnesota follow the increases in total gross farm income per farm in the 1970s but not in the 1980s. From their peak in 1981, land values decline rapidly while gross farm income ceases to rise but does not fall. Net income measures appear to coincide with some changes in land value but they do not always move together. Statistical analysis of the data from 1940 through 1988 show that the best predictor of land values is a combination of income measures and an ARIMA model. Based on this and other literature combined with the basic theoretical concepts of supply and demand, a comprehensive model of the land market that focuses on the determinants and shifters in the supply and demand functions is identified. Other considerations in the land market including environmental issues and relative property rights of renters vs. owner operators under different institutional and legal structures are discussed.

LAND VALUES AND FARM INCOMES IN MINNESOTA

by Kent D. Olson and Michael D. Boehlje

In the 11 years from 1970 to 1981, farmland values in Minnesota rose more than five times their 1970 value (Table 1, Figure 1). Then by 1988 farmland values fell to less than half of their 1981 value. However, the 1988 values are still more than double the 1970 value. The statewide land values rose from $227 per acre in 1970 to $1,310 in 1981 and then fell to $523 in 1988. Similar numbers (with even proportionately larger changes) can be seen in the southern areas of Minnesota.

In this paper we look at how well movements in farm income have matched the movements in land values over this same time period and how other factors can be incorporated into a more comprehensive model of the land market. First, we review previous attempts to describe the land valuing process and the variables included in this process. Next, we look more closely at the relationships between farm income and farmland values in southern Minnesota. Finally, we discuss the development of a land market model which encompasses both the demand and supply side of the markets.

PREVIOUS RESEARCH

In 1979 Pope et al., published a review and updating of several models of U.S. farmland prices. They reviewed three simultaneous models and one single equation model and evaluated their structural credibility when estimated using a longer time series of land price data. The three simultaneous models were Reynolds and Timmons (1969), Tweeten and Martin (1966), and Herdt and Cochrane (1966). As reported by Pope et al., all three models did reasonably well in explaining variations in land prices for the time period selected.

Reynolds and Timmons used data from 1933 to 1965 and found land price variations to be explained by expected capital gains, predicted voluntary transfers of farmland, government payments for land diversion, conservation payments, farm enlargement, and the rate of return on common stock.[1] When Pope et al., reestimated the model using data from 1946-72, four of the eight signs in the price equation reversed and only one coefficient was statistically different from zero (P>.05).

Tweeten and Martin used a five-equation model for explaining changes in farmland values from 1950-1963 and found two major determinants: capitalized benefits from government programs tied to land and pressures for farm enlargement.[2] Pope et al., reestimated their model with data from 1946-72 and found many sign changes and lack of statistical significance; "for example, regardless of the estimation technique, all coefficients except lagged price (and possibly farm numbers) are statistically insignificant in the price equation" of the updated model (p. 108).

Herdt and Cochrane, using data from 1913-62, found that "technological progress in conjunction with government supported output prices led to

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[1]Pope et al., 1979, p. 108.

[2]Ibid.

rising farmland prices."[3] Pope et al., reestimated their model with data from 1946-72 and found that the problems of sign reversal were slight because the coefficients were also insignificant. Herdt and Cochrane's model was defined by

Ns = f(P, R, U, Lf), the supply equation;

Nd = f(P, R, T, Pr/Pp, G), the demand equation; and

Ns = Nd, the identity

where Ns is the number of farms supplied, Nd is the number of farms demanded, P is the average value per acre of U.S. agricultural real estate in current dollars, R is the rate of return on nonfarm investment, U is the unemployment rate, Lf in the amount of land in farms, T is the USDA productivity index, Pr/Pp is the ratio of the index of prices received by farmers to the index of prices paid by farmers, and G is the wholesale price index.[4]

Klinefelter (1973) presented a single equation model which used net returns, average farm size, number of transfers, and expected capital gains to explain 97 percent of the variations in Illinois land prices between 1951 and 1970. Pope et al., also estimated a similar model using 1946-72 data and found some implausible signs but a very high explanation of price variation (adjusted $R^2 = .989$).

Pope et al., used the reestimated Herdt-Cochrane model and Klinefelter model to forecast both within the 1946-72 sample period and the beyond sample years of 1973-75. They also estimated and forecast with a Box-Jenkins, autoregressive moving average model. In comparing these

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[3]Ibid.

[4]Ibid.

three models, Pope et al., found that all three underestimated the prices in 1973-75 but that the Klinefelter single-equation model performed better in terms of RMSE (root mean square error) than the Box-Jenkins model which performed better than the Herdt-Cochrane simultaneous model. They conclude that simple, time-series models and single equations (which may have microeconomic foundations but not explain the market), do a better job in explaining the variations in land prices than econometric models which incorporate greater structural details and supposedly have greater causal foundations but do not perform well outside of their original sample period.

In more recent years, Barry (1980) has presented the use of the capital asset pricing model (CAPM) in the analysis of farm real estate prices. The CAPM assumes that equilibrium rates of return (and thus, prices) on individual assets adjust to levels that reflect the risk each asset contributes to a market portfolio of all assets.[5] With his results, Barry concludes that farmland (at a national or regional level) contributes little systemic risk to an investment portfolio, that farmland has paid premiums above those needed to compensate for the systemic risk, and that the nonsystemic risk could be eliminated by effective diversification. Barry sites several shortcomings of the CAPM: lack of inflation adjustment, a thin real estate market, high transactions costs, lack of portfolio diversification on the part of land owners, and data quality concerns.

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[5]Sharpe(1964) and Lintner (1965) first presented the CAPM and its theoretical underpinnings.

Irwin et al. (1988), modified Barry's CAPM to include inflation, broaden the market definition, and lengthening the sample period. With this modification, they conclude that farmland contributes little systemic risk to a well-diversified portfolio, farmland returns are not strongly related to the performance of the market portfolio, farmland returns have not been relatively low during the 1947-84 period, and returns have been systematically related to uncertain inflation. However, they base these conclusions on an estimated model in which only the inflation coefficient is significant ($P<.05$, p. 585).

Another area of past research efforts affecting farmland values involves the calculation of the value of the land to a potential buyer, especially the farmer-buyer. A method most often employed here is capital budgeting which involves, in its simplest form, estimating the expected future returns per time period (R), selecting an appropriate discount rate (r), and calculating the value of the land (V) by:

$$V = R / r \qquad (1)$$

Using this model, farmers should be willing to bid up to the capitalized value of the land (V) but to go no higher. Stated in other words, the purchase was not made if the required rate of return (d) was not met or exceeded. Boehlje and Eidman (1984, p. 534) expand the income capitalization formula in this manner:

$$V = (R - E - L - I) / r \qquad (2)$$

where V = earnings value, R = total cash farm receipts, E = total cash farm expenses, L = the value of the operator's and unpaid family labor, I = interest on nonreal estate capital, and r = the capitalization rate. Extensions of this simple model were used to estimate farmland bid prices in a simulation study of public policy impacts (Boehlje and Griffin, 1979), to incorporate expected capital gains into the formula (Kletke and Plaxico, 1976), and to analyze the impact of changes in export demand on the market for U.S. farm land (Runge and Halbach, 1988).

This capital budgeting or income capitalization approach has been used widely in extension work in the U.S. to help farmers determine: (1) the value of additional land, and (2) the maximum cash bid possible given the available cash for a down payment and the available cash flow for continuing debt service. Examples of extension materials for this use include Hasbargen and Thomas (1978) in Minnesota, Willett and Wirth (1980) in the western states, and Willett (1981) in a national farm magazine. This approach has also been used in computerized decision aids for farmers which are available at many universities (e.g., Hasbargen and Craven, 1981). In all of these publications, the capitalization formula was expanded to include income from other parts of the farm business (and even nonfarm sources of cash), tax consequences of additional interest payments and depreciation including capital gain considerations, expected rate of change in the net return to land, expected rate of change in the market price of land, family living expenses, and financing considerations such as the interest rate, down payment, and length of loan.

Rosenfeld (1988) refutes the value of the capital budgeting or income capitalization model for farmers on the basis of a survey of the objectives of farmers and their families in the farmland market. He found that most of the respondents were interested in buying farmland for the long-term viability of the farm and very few mentioned an objective reflecting a required rate of return (p. 54). Rosenfeld found that 92% of the respondents said they used a procedure other than capital budgeting to determine their farmland purchase prices. After asking what these other procedures were, Rosenfeld concludes that only between 7% and 15% of the respondents had a required rate of return in mind when they made a land purchase.

Based on these results, Rosenfeld develops a cash flow model to determine the repayment capacity of the potentially expanded farm (after accounting for expected household consumption and savings) as the prime determinant of the maximum bid price of the farmer. Rosenfeld argues that it is not a question of comparing rates of return between investments but it is a question of whether the farm family can afford to pay the price to achieve its goal of farm ownership and/or expansion. Thus, the model he develops is very similar to the materials used by extension (and cited above) to help farmers determine the maximum bid price based on cash available for the down payment and debt repayment.

More recently, both Falk (1989) and Clark and Fulton (1989) have shown that the traditional models of farmland price formulation do not perform well statistically when tested against actual data. Falk used Iowa farmland price and rent data and methods from the financial economics literature to test and subsequently reject the present value model of farmland price determination. Falk determined that the model's statistical failure was of economic importance and not likely due to measurement error or sampling error. However, Falk's model does not allow for negative real interest rates which occur in Federal Land Bank's time series data (Raup, 1989). Falk also determined that the Iowa farmland market was not characterized by rational bubbles; that is, prices departing from their fundamental values due to the participants' beliefs in the impact of an actually irrelevant variable. Using data from previous land price analyses, Clark and Fulton reject the basic premise of these papers. First, they cannot reject the hypotheses that two unit roots characterize the data instead of the original assumptions of either explosive or one unit roots. Second, they find the time series representation of land prices and of land rents to be inconsistent with each other. In his 1989 outlook paper on farmland values and rents, Scott commented that when supplied with a longer time series (1950-1981), Burt concluded that his original model using 1960-1981 data (Burt, 1986) "did not do as well with the longer series" (Scott, p.1) and that interest rates were not statistically significant.

In these studies, one common thread has been that models either did not perform well with the original data or did not perform well with a different or longer data series. Also, two recent papers showed that the Ricardian or present value models of land prices did not explain the relationships between the time series of land prices and rents. In the next sections, we look at the recent trends in land values and farm incomes in southern Minnesota, evaluate the relationship between land values and farm income in light of these previous studies, and also explore the ability of land values to predict themselves.

FARM INCOME DATA

The farm income data used in this paper are obtained from two farm record associations in southern Minnesota (Figure 2). The Department of Agricultural and Applied Economics (and its predecessors) has had a long affiliation with these associations.[6] In 1927, Better Farming Clubs started with 128 members in 6 counties of southeastern Minnesota; their first reports were for 1928. In 1988 the Southeastern Minnesota Farm Business Management Association had 79 members in 18 counties and 1 full-time field staff. In 1939, 175 farmers in 11 counties formed the Southwest Minnesota Farm Management Service; their first report was for 1939. In 1988, the Southwestern Minnesota Farm Business Management Association had 212 members in 16 counties and the equivalent of three full-time field staff.[7]

The association members follow uniform accounting practices on their farms. The field staff analyze each farmer's records at year-end by using FINANX, one of the FINPACK family of computer programs developed within the Department's Center for Farm Financial Management. These year-end analyses subsequently are gathered, summarized, and reported through meetings and publications. Since the associations began, a departmental faculty member has participated in these efforts through overseeing and subsidizing the summarizing and publishing of the summaries. The Minnesota Extension Service has participated by subsidizing the salaries and offices of the field staff and providing split appointments for the field staff between association duties and regular extension duties. The Associations pay the unsubsidized portion of the field staff's salaries and all operating costs of the field staff. Association members pay dues

[6]Early notes indicate that crop cost accounting routes started in 1902 with livestock and whole farm costs added in 1904. A mail-in program was started in 1913.

[7]In the Southwest Association, these 3 full-time equivalents are split between 4 people. These people are also area extension agents with the Minnesota Extension Service.

which start from a base of $450 (in 1989) for a sole proprietorship without any other complicating factors. Partnerships, corporations and farms with other activities which increase the tax reporting requirements pay higher dues.

These Associations cover the major corn-soybean area of Minnesota, but do not cover the wheat and sugarbeet areas of west central and northwest Minnesota. The southeast region includes one of the major dairy areas within the state. The southwest region has been a beef and hog feeding area with increasing emphasis on hog feeding as beef feeding has moved out of the Midwest to the southern and western areas of the United States. Olson and Tvedt compared the membership of the two Associations to the general population of farms in Minnesota (as measured in the U.S. agricultural census) and found that Association members are typically larger in terms of crop acreage, more likely to be diversified with both crops and livestock, and have larger livestock operations than their livestock counterparts. Thus, although there are a few part-time farmers who are members, we assume the Association data to represent the larger, commercial, full-time farms. We also assume that members are on the average better managers than the general population of farmers, but we have not tested this assumption.

These Associations are the source of the farm income data we are using in this paper. More detailed information on income, expenses, crops, and livestock can be obtained in the annual reports (for example, Olson et al., 1989a, 1989b).

TRENDS IN FARM INCOME

There are four measures of income which we use in this paper (Tables 2 and 3). Gross farm income is the total receipts from the sales of products, services such as machine work hired to other farmers, government payments, and other farm income; nonfarm income is not included. Net cash farm income is gross farm income minus the total of cash expenses including variable and fixed expenses. Accrual net farm income is net cash farm income adjusted for (1) changes in inventory levels and (2) depreciation and other capital adjustments such as asset sales and purchases and asset value changes. Extraordinary events such as asset repossessions, debt forgiveness, and land value appreciation and devaluation are not included in the calculation of accrual net farm income. The value of production is gross farm income minus purchased feed and purchased feeder livestock and adjusted for inventory changes. A farm's value of production is a more accurate measure of the actual production on a farm within a year. Gross farm income may include sales of products and animal gain from a previous year and not include products and animal gain produced within that year but sold in a future year.

Several things can be noted in both associations when we compare the farm income measures per farm to the land value per acre (Tables 2 and 3 and Figure 3). Gross farm income and the value of production follow a generally upward pattern from 1970 to 1981 when they appear to reach a plateau. The value of production has a more volatile pattern than gross farm income. Net cash farm income has a slight upward movement and accrual farm income has either no noticeable or only a slight upward movement. Accrual net farm income is more volatile than net cash income.

The movements of gross farm income and the value of production match those of land value better than either net cash farm income or accrual net farm income from 1970 to 1981. However, starting in 1981, gross farm income and the value of production appear to reach a plateau and do not fall compared to the large declines in land values. Increases in accrual net farm income per farm coincided with increases in land values in 1971-73, 1976-78, 1980-82, and 1985-87; but this correlation is not consistent in all years especially 1973-76, 1978-80, and 1981-83. Converting to real dollars does not change these observations.

Converting the four income measures from a per farm basis to a per crop acre does not yield any more explanatory power of why land values changed between 1970 and 1988 (Figure 4). The income measures per acre still roughly follow the same patterns as the per farm income measures. But, compared to the movements of land values, there are no strong, consistent movements up and then down in any of the per acre income measures.

STATISTICAL ANALYSIS OF MINNESOTA DATA

Previous studies of land values have used land rent as the return to land. In this section, three measures of farm income are used as proxies for the return to land. These income measures are used instead of rent since income is a direct measure of what the land produces in a year regardless of ownership and since rents may be determined in their own pattern and may exhibit different fluctuations than annual income measures.

In the graphical analysis (Figures 3 and 4), the value of land appears to follow the movements of the gross income measures up to the early 1980s. However, when land values fall in the 1980s, the gross income measures fluctuate but do not exhibit a similar decline. The gross income measures are the gross cash farm income and the value of production. Also, the value of land appears to be unrelated to the movements of the two net income measures (net cash farm income and accrual net farm income).

To test this statistically, the data from the Southwest Minnesota Farm Business Management Association was expanded back to 1940, its first year of operation. Simple regression analysis shows that there is an autocorrelation problem when the income measures are used by themselves (Table 4). Before correction, it is obvious that gross cash farm income explains more of the variation in land values than does either net cash farm income or accrual net farm income. When corrected for autocorrelation (using the Cochrane-Orcutt procedure in the TSP package), both gross cash farm income and accrual net farm income are significant ($P<.01$ and $P<.05$, respectively) but the autocorrelation variables (AR(1)) have greater t-statistics. Net cash farm income becomes insignificant ($P>.20$) in the corrected model. Similar results were obtained when the income measures were expressed on a per acre basis (Table 4).

The value of land as calculated by Schwab and Raup is a smoothed function of the land prices obtained by an annual survey. This smoothing is done by considering only those surveys returned by people in the same geographical area for the current year and the past year. To remove any potential bias of this smoothing, the annual prices obtained from the survey were used to evaluate the impact of the gross and net income measures. Using these prices, the simple regression analysis results are similar to those obtained with the smoothed land values (Table 5). That is, autocorrelation is present and gross income does a better job of explaining changes in annual survey prices than the net income measures.

With both the land values and the annual land prices, the autocorrelation coefficient explained more of the variation than the income measure. This suggested that there were slowly changing variables present but unaccounted for in the simple models. To analyze this phenomena farther, statistical tools for time series data were used[8]. Evaluation of the autocorrelation function of the value of land showed a strong indication of an integrated term (Figure 5a). That is, the value of land tends to drift over time. To remove this drift, the first differences are taken. Analysis of the autocorrelation function of the first difference of the land values indicated the presence of an integrated term in the first difference (Figure 5b) and the need to take a second difference to remove this drift. The autocorrelation function of the second difference did not show this presence (Figure 5c), so further analysis was done on the second differences of the land value series.

The ARMA model was estimated using the methods outlined in Hall and Lilien (1987), Judge et al. (1985), and Pindyck and Rubinfeld (1976). Using second differences, the autocorrelation function showed the potential for significant relationship lags of 1, 2, 4, and 6 years (Figure 5c). A moving average (MA) model of these lags was estimated which showed the lag of 2 to be insignificant ($P>.20$) (Table 6). The subsequent MA model with lags of 1, 4, and 6 had significant coefficients

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[8]MicroTSP(c) (Hall and Lilien, 1987) was used for the analysis.

(P<.20) but did not explain the variation very well (adjusted R^2=0.18). Potentially significant partial autocorrelations were noted at lags of 1, 2, 4, 6 and 9. An autoregressive (AR) model of these lags was estimated which showed the lag of 4 to be insignificant (P>.20): the subsequent AR model had significant coefficients (P<.20) and an improved adjusted R^2 (0.47). Fitting the AR and MA models together in an ARMA model shows the first MA lag to be insignificant. The subsequent ARMA specification has an adjusted R^2 of 0.59.

In this time series analysis, there has been the assumption that other variables do not affect land values. However, that is most likely an erroneous assumption. Even if income does not explain movements in land value very well, income is a critical component of the conceptual model for determining land value. To evaluate the statistical relationships between land values and income measures, the crosscorrelations of lags are estimated (Hall and Lilien, 1987). Potentially significant relationships between the value of land and gross cash farm income are seen in lags of 0 through 4, 6, and 8 (Figure 6a). Between the value of land and accrual net farm income, potentially significant relationships are seen in lags of 0 through 8 (Figure 6b). Upon estimation, the gross cash farm income lags of 0, 1, 3, 4, and 6 were significant (P<.01) with an adjusted R^2 of 0.75 and a indeterminate Durbin-Watson test (Table 7). All of the accrual net farm income lags were significant (P<.20) with an adjusted R^2 of 0.82 (Table 8).

Combining both the time series analysis and the regression of land values upon income measures shows the explanatory power of the income measures and the presence of slowly changing, but unobserved variables captured in the land value series itself. Using gross cash farm income, all the income lags found in the simple regression analysis were significant (P<.01); but only the autoregressive and moving average lags of 6 were significant (P<.01 and P<.05, respectively) in the combined analysis (Table 7). Using accrual net farm income, all the income lags were significant (P<.01); a moving average lag of 4 and an autoregressive lag of 9 were significant (P<.01 and P<.20, respectively) (Table 8). In this combined analysis, accrual net farm income had a slightly better explanatory power (adjusted $R^2 = 0.90$) compared to the gross cash farm income (adjusted $R^2 = 0.84$).

The number of lagged observations of accrual net farm income was troublesome to the authors. So based on the crosscorrelations (Figure 6b), an abbreviated model was estimated with lags of 0, 1, 2, 7, and 8 (Table 8). This model was reduced and combined with time series analysis to produce a model with the current and once lagged net farm income and autoregressive lags of 1, 2, and 9. This latter model had an adjusted R^2 of 0.65.

In this "first-cut" statistical analysis, the movement of land values over time has been modeled as a function of farm income and past changes in land values. The combination of time series analysis and lagged income values produced the best predictors of land values. Further analysis of the relationships between land values and farm income is needed using the income measures on a per-acre basis and on other data sets.

For forecasting, time series analysis can be very useful. However, the results do not explain the underlying land market dynamics. To understand the land market structure and the forces within that market, a structural model is needed. This has been done before but Pope et al., have shown how these models have performed once a different time series is used to evaluate them. In the next section, a theoretical structural model of the land market is developed which incorporates both supply and demand of land.

A SUPPLY/DEMAND FRAMEWORK OF THE LAND MARKET

The empirical data presented earlier suggests that land values are not exclusively determined by farm income. The subsequent literature review indicates a number of other determinants, but much of the discussion and empirical analysis has focused on income and other "demand factors" that are expected to impact land values. With a few exceptions, only limited emphasis has been placed on those factors that influence the supply function, and the entire set of "demand factors" has not been integrated in the analysis. More specifically, much of the empirical work, and particularly the extension applications, has assumed that the supply function for land is constant or at best very inelastic. This assumption is only partially true when viewing total supply given that significant acreages of land have been made available for production through drainage, irrigation and other improvements. New crop varieties have made land previously presumed to not be productive because of soil characteristics or climate, an integral part of the agricultural land base (for example, previously marginal producing lands in colder climates).

Furthermore, if supply is alternatively defined as the quantity available or offered to the market at any point in time, the assumption of fixity is no longer valid. Thus, it is argued that the land market is characterized by the typical economic model for any product, service or asset with a supply function and a demand function. The purpose of this discussion will be to describe the specific variables that both shape and shift the supply and demand functions for farm real estate. Hopefully, this general model will provide a uniform (at least partial) framework for further research on land values in different geographic, legal, institutional, and political environments.

The Demand Function

Our first task will be to discuss the factors (variables) that shift and shape the demand function for farm real estate.

Income. Expectations of the future income stream from land are a well recognized determinant of value; numerous theoretical and empirical studies have documented the importance of this determinant of land prices. As suggested by Melichar, not only are expectations of the future level of income important, but expectations as to the long run growth or decline in income are also a major consideration. Recognition of the consistent rise in farm earnings per acre during the 1960s and 70s led to the "growth stock" approach to land valuation. The essence of this argument is that any asset which exhibits a sufficient history of growth in income (dividends or rents) will have a higher price earnings ratio than an asset with similar current levels of income that does not reflect that same history. In essence, the argument is simply that investors bid the expectations of continued growing incomes into current asset values, thus resulting in a value that is higher than would be supported by current income levels. Melichar's work suggests that land prices in the U.S. during the 1970s reflected an expectation on the part of purchasers that farm incomes would grow at a rate consistent with their historical trend of the 1950s, 60s and early 70s, and thus were higher than one might expect based on current levels of income alone. In similar fashion, one might hypothesize that the land value declines in the U.S. of the 1980s might have been fed by an expectation of continued declining incomes that resulted in values that were lower than would be suggested by current levels of income during that period. Melichar, along with Harris and Nehring, indicate how expectations of growth or decline in income can be built into the capital asset pricing model through a reduction or increase in the discount rate, respectively.

<u>Interest rates</u>. The capital asset pricing model suggests that interest rates might be another important determinant of land values. The influence of interest rates on the value of assets (assuming a specified income level) is proven daily in bond markets; as interest rates rise bond values decline and vice versa. It is reasonable to hypothesize that interest rates would have a similar impact on land values. Note that the interest rate of concern here is the real rate, or nominal rates adjusted for general inflation.

Let us return to the U.S. land market of the 1970s and 80s to develop hypotheses concerning the role of interest rates on land values. During the decade of the 1970s, monetary policy combined with average cost pricing procedures of the Federal Land Bank and other mortgage lending institutions resulted in relatively low (in fact negative during some periods of time) real rates of interest. A logical argument is that these low real rates of interest combined with relatively high per acre net returns and expectations that these returns would continue to rise resulted in very high land values during the decade of the 70s. In the following decade of the 80s, changes in monetary policy and pricing practices of lending institutions resulted in relatively high real interest rates -- rates of 8% to 10% during some periods. The hypothesis is that the dramatic decline in land values by as much as two-thirds in some parts of the U.S. was significantly influenced by these dramatically higher real rates of interest combined with lower levels of income and the expectations that incomes would continue to decline over time.

Financing. Land purchases are frequently financed with unique and favorable financing arrangements. As noted earlier, pricing policies of some lenders have resulted in favorable interest rates for land mortgages compared to that available for other assets. And particularly during the 1970s in the U.S. real estate market, installment land contracts (which in essence provided seller financing for land purchases) were frequently negotiated at substantial interest rate discounts compared to market conditions. As suggested by Boehlje and Reinders, these favorable financing arrangements uniquely associated with a particular asset had a value that was frequently reflected in the price of that asset. In essence, the purchaser of the asset was simultaneously paying for the favorable financial terms or "cheaper than market rate money" along with the inherent income generating capacity of the asset. Consequently, a premium price was being paid for favorable financing terms that were exclusively linked to the land asset. With the declining interest in land contracts, and changes in pricing policies of financial institutions, this financing premium has most likely all but disappeared in recent years.

Location. Location has always been a major consideration in farm real estate pricing. Farmers have frequently argued that they can justify paying higher prices for nearby properties based on superior knowledge of the production characteristics of those properties, reduced transaction costs in managing and operating those properties as add-on units, and economies of scale and size associated with expansion on a continuous land base. Location vis-a-vis market outlets is also a critical consideration because of transportation costs as evidenced by differential prices for similar quality land in the Midwest with dissimilar access to transportation and distribution systems. Numerous other "location" dimensions may be important including the financial strength of neighboring farms, the climatic environment of the locale, etc.

Portfolio balance. A factor important to some investors in the farm real estate market is the portfolio balance or diversification attributes of farm real estate. Farmland has a unique set of income, capital gain, and risk characteristics that complement those of other assets, thus giving a synergistic, portfolio facet to a farmland purchase. Although this portfolio concept may be most applicable to the nonfarm investor participant in the market, it is not foreign to a farm operator who combines farmland and other agricultural investments with financial assets or even nonfarm business investments as an attempt to reduce risk exposure and balance the asset portfolio.

Tax considerations. Work by Davenport et al., and others, documented the significant tax considerations that have been important in the past in the farm real estate market in the U.S. The interaction of the provisions that allowed the deductibility of interest and land improvement expenses, the preferential treatment of capital gains, and the use of the cash accounting system made farm real estate an attractive tax shelter, particularly for high income investors whether that income was generated from farm or nonfarm sources. Changes in the tax law in the U.S. eliminating the differential taxation of capital gains, restricting the deductibility of certain interest expenses and other land improvement outlays, and limiting the use of farm losses to offset income from other sources has made land a much less attractive tax shelter than in the past. But such changes in tax rules are not permanent--in fact discussions were underway to reinstate differential treatment of capital gains under the U.S. tax code, but have been dropped for the current Congressional session. Differential tax rules exist in other countries also. Consequently, tax considerations are an important dimension of the demand function for farm real estate and must be incorporated in any numerical or empirical analysis of farmland values.

Development and nonfarm uses. In particular parts of the countryside in the U.S. and Europe, a major determinant of the value of farmland is its use for nonfarm development purposes, whether that purpose be for housing, industrial development or urbanization in general. In contrast another nonfarm demand for farmland is for "open space" to relieve the pressures of urbanization and congestion as well as provide space for enhancing environmental, wildlife and aesthetic attributes of the countryside. With the increasing pressures for urbanization and congestion, the twin demands to use farmland for development and open space purposes will increase.

Government policies. A final variable that significantly impacts the demand function for farmland is government farm policy. In the U.S. the best and most explicit examples are program base provisions of feed and food grains and other farm programs including tobacco, cotton, peanut and rice programs. In essence, the program base defines the number of acres which qualify for government subsidies. Thus land with a program base will exhibit lower income risk and is likely to have higher mean returns over time than land without a government program base. Government subsidized irrigation projects, zoning regulations and environmental regulations and constraints can also have a significant impact on land use and thus land values.

The Supply Function

The following variables are expected to have a significant impact on the shape of and shifts in the supply function for farm real estate.

Retirement patterns. The retirement age and the disinvestment strategy of farmers has a significant impact on the availability of land to the market. But many farmers continue to own farm real estate well beyond their retirement years; some rent it out to other operators and others continue to be more actively involved in managing the property through custom farming or other operating arrangements that frequently involve family members. Even at the death of the husband, the surviving spouse may continue to own the land. And in the case of a multi-generational farming operation, farm real estate will likely be transferred to the heirs through a nonmarket mechanism such as a gift or bequest. And sales among family members are frequently not at market prices, so data on such transfers is suspect from the perspective of the reliability of the market information. The importance of this phenomena of disinvestment strategies and retirement plans of farmers in determining the supply of land and the shape of the supply function merits substantial analysis.

Age distribution. Related to the above argument concerning disinvestment behavior of farmers during the retirement years is the issue of age distribution of the farm population. As a larger proportion of farmers in the U.S. become of retirement age, an increasing proportion of farm real estate will be subjected to the disinvestment behavior and strategies noted above. It should be noted here that if farmland ownership becomes dominated by nonfarm investors rather than owner-operators, the age and disinvestment/retirement variables noted above would no longer be significant determinants of the supply function of farm real estate.

Heir and investor investment strategy. For that portion of farm real estate owned by investors (including farmer investors and off-farm heirs), the investment strategy they follow will have a significant impact on the quantity of properties offered to the market. Such investors will likely respond to the typical variables in deciding whether to maintain farmland investments or offer them to the market including rates of return on farmland compared to alternative investments, tax considerations, the potential for capital gains, the merits of portfolio diversification using farm real estate, etc. These variables have already been discussed in detail as major determinants of the demand function for farm real estate; here they are identified as major factors influencing supply in the context of quantities of farmland that investors will sell or hold in their investment portfolio.

Cost of upgrading. The relative cost versus benefits of investing in land improvements will also impact the total supplies available. Benefit cost ratios that provide incentives for drainage and irrigation development as well as land clearing will result in additional acreage eventually being available to the market. More specifically, during the decade of the 1970s, significant amounts of previously-limited productivity land in the Western Corn Belt were brought into feed grain production. With the declining prices and higher costs (and changes in the U.S. tax code which resulted in reduced tax benefits of such development) of the 1980s, such development has become almost nonexistent.

Financial stress. A final variable influencing the amount of land offered to the market is that of financial stress. "Forced sales" of farmland due to debt servicing or other financial problems can and has resulted in additional properties being offered to the market in the U.S. It is hypothesized that this phenomenon was an important contributor to the declining land prices in the U.S. during the 1980s. Additional market offerings due to financial stress occurred through forced liquidations, bankruptcies and sales of acquired property by lenders.

The contribution of financial stress to declining land prices can and does occur in spite of decreased numbers of transactions. The lending community held significant amounts of acquired property during the 1980s which by regulation or management policy would eventually need to be transferred to more permanent ownership. It is argued that this significant excess supply of land being held off the market by lending institutions, in fact, had a depressing impact on prices much like any excess supply or surplus in the asset market or "reserves" in the commodity market.

WHAT HAPPENED IN THE 1980S

The dramatic decline of land values in the U.S. during the 1980s will be used to illustrate the potential applicability of the model just outlined. Figure 7 identifies the supply/demand conditions in the land market during the late 1970s with P_0 and V_0 denoting equilibrium prices and volume of land sales, respectively, given demand and supply functions D^0 and S^0, respectively. In the early 1980s incomes dropped and interest rates rose, resulting in significant financial stress. Land prices dropped dramatically, but sales transactions also declined. Given that both price and volume decreased, it appears that both supply and demand curves may have shifted during this period of time, and the indirect impact of land held by creditors was a significant factor in the market. If only demand had shifted left (D^1 in Figure 7), as suggested by declining incomes and higher interest rates, the traditional inelastic supply function model would explain the lower prices but not the reduced sales. However, with an elastic supply function, reduced prices and lower sales would result from a shift to the left in the demand function (Figure 8). Furthermore, if a creditor's acquired property is added to the "normal" supply function, even though it is not directly for sale, we can see how the price of farmland could be set by a reduced demand and increased supply (D^1 and S^1 in Figure 8). The result would be dramatic drops in price with only modest declines in transactions. These arguments and the events of the 1980s suggest that: (1) the supply function for land may be more elastic than we have recognized in traditional land pricing models, and/or (2) that land held by creditors in acquired property inventories did have a depressing effect on prices.

FURTHER CONSIDERATIONS IN LAND MARKETS

Although the land valuation model discussed thus far is more comprehensive than many proposed, there are some additional dimensions of land valuation and land market dynamics that should be identified. As suggested in the earlier discussion, environmental/open space considerations are becoming increasingly important in the land market. Farmland is an important dimension of the environment and its quality; it can contribute to environmental problems through air pollution and water degradation, and it can assist in solving environmental problems by providing open space and disposal sites for hazardous, contaminated waste. Many of the environmental/open space considerations in allocating and valuing the land resource occur through nonmarket phenomena, so zoning and land use regulations have become a significant factor in the land market. The incorporation of these specific regulations and constraints in supply/demand modeling in the farmland market along with the explicit recognition of environmental/open space impacts on the elasticity and shift in supply and demand functions merits substantial further analysis and investigation.

A second major consideration in the land market is the issue of ownership versus operation of that land and the relative property rights of owners versus operators and/or tenants versus landlords. Given the current short-term leasing arrangements dominant in the U.S., there is significant control risk associated with leasing farm real estate. This is quite different in Europe where longer-term lease arrangements appear to be more dominant. In fact, in contrast to the U.S., Europeans appear to have longer-term ownership patterns in farmland as well as longer-term lease arrangements. Purchasing farmland reduces control risk, but if such purchases are debt-financed, they typically result in increased financial risk as evidenced by the financial stress of the 1980s in the U.S. This very significant issue of property rights as delineated by the legal/institutional structure in various countries, and the implications of relative property rights of owners versus operators on market values, land utilization, purchasing and selling behavior, etc., is also a critical issue meriting significant analysis for complete understanding of the dynamics of the land market.

One possibly useful concept in understanding the land market is that it is not really a single market (even ignoring the common arguments of a local versus the national market in farm real estate), but two markets--an ownership market and a rental market. Furthermore, there are a multiplicity of players in these two markets including lending institutions with acquired property, owners of farmland, nonfarm investors in farmland, operators who may want to own farmland, operators who may want to rent farmland, etc. In essence, the land market may be much more complex than our traditional modeling techniques reflect.

A final consideration in the land market is the role that it has played and may continue to play as part of the financial and economic adjustment process within the agricultural sector. During the decades of the 1940s, 50s and 60s in the U.S., labor moved out of agriculture in an attempt to generate equilibrium rates of return with other sectors of our economy. With less labor now available in the agricultural sector to make such adjustments and more limited opportunities for capital-labor substitution, one might argue that a significantly larger portion of the adjustment process to generate competitive rates of return between agricultural and non-agricultural sectors occurs in the land market. Consequently, when incomes increased in the 1970s, land prices increased; more significantly when incomes decreased in the 1980s, land values declined precipitously rather than significant amounts of labor and non-land capital leaving the agricultural sector. In essence, one might argue that land has replaced labor as the major shock absorber in equalizing returns between the agricultural and the non-agricultural sectors in the U.S.

CONCLUSION

A review of the empirical data for Minnesota and the literature suggests that land values are impacted by a broader set of variables than farm income. It has been suggested that land values are a function of both supply as well as demand factors. A number of shifters and shapers of both the demand and supply functions in the U.S. farm real estate market have been identified in this discussion. It is suggested that this general economic model is applicable under a wide variety of institutional and geographic circumstances in Europe as well as the U.S. Interesting issues for collaborative research would include estimation of land supply and demand functions in the U.S. and various countries of Europe and a comparison of the elasticities of these functions. Furthermore, detailed analysis of those factors that shift the supply and demand functions in the U.S. and Europe could provide valuable information on the dynamics of adjustment in the farm real estate markets in different political/economic settings.

Table 1. Land values per acre southern Minnesota: 1970-1988

Year	Area of Minnesota		
	Statewide	Southeast	Southwest
		($/acre)	
1970	227	317	347
1971	232	333	351
1972	248	370	379
1973	298	433	459
1974	423	576	675
1975	525	674	844
1976	667	856	1106
1977	794	1027	1316
1978	889	1191	1421
1979	1040	1453	1620
1980	1120	1526	1750
1981	1310	1709	2083
1982	1179	1504	1875
1983	1065	1354	1669
1984	927	1164	1401
1985	686	861	967
1986	515	603	696
1987	480	558	671
1988	523	648	784

Table 2. Farm numbers, size and income measures for the Southeastern Minnesota Farm Business Management Association: 1970-1988

Year	Farm Numbers	Average Crop Acres per farm	Gross Farm Income	Net Cash Farm Income	Accrual Net Farm Income	Value of Production
			($/farm)			
1970	113	258	42,224	16,301	12,574	34,469
1971	113	276	43,780	13,864	11,464	35,099
1972	114	287	51,741	20,233	19,416	46,273
1973	118	298	71,558	28,279	45,998	84,926
1974	112	304	82,899	35,976	31,576	72,960
1975	101	333	80,015	25,382	20,314	69,247
1976	78	293	93,458	34,032	27,578	72,373
1977	80	328	115,217	40,265	32,477	89,147
1978	74	333	133,803	49,845	55,428	114,896
1979	83	307	141,032	48,681	35,061	101,555
1980	86	331	161,148	49,952	40,853	124,860
1981	63	327	160,457	48,013	26,117	113,376
1982	54	347	202,185	51,253	24,553	138,358
1983	53	N/A	178,365	61,996	34,473	170,215
1984	57	363	187,562	43,514	20,724	181,517
1985	59	423	197,842	46,680	16,709	190,882
1986	61	376	190,124	49,034	25,180	173,619
1987	62	365	190,481	53,679	45,197	194,420
1988	63	348	187,712	52,553	41,829	187,789

Table 3. Farm numbers, size and income measures for the Southwestern Minnesota Farm Business Management Association: 1970-1988

Year	Farm Numbers	Average Crop Acres Per Farm	Gross Farm Income	Net Cash Farm Income	Accrual Net Farm Income	Value of Production
			($/farm)			
1970	140	390	71,091	18,072	12,087	40,803
1971	146	390	70,518	9,959	12,137	41,497
1972	156	417	79,931	14,299	27,173	62,202
1973	144	430	118,308	28,489	57,569	106,001
1974	145	452	136,606	49,312	25,905	81,921
1975	140	451	125,965	33,206	21,497	80,982
1976	124	438	136,473	35,359	16,657	69,975
1977	169	447	136,950	29,848	33,063	91,114
1978	183	460	177,366	37,553	62,473	138,757
1979	179	473	203,470	39,308	28,746	111,919
1980	170	469	236,231	43,041	46,713	148,445
1981	172	478	261,766	51,443	2,272	114,372
1982	180	480	247,413	41,962	25,838	147,570
1983	182	N/A	251,287	59,653	27,844	201,051
1984	168	519	259,338	41,874	9,872	206,568
1985	180	552	237,875	52,011	5,487	185,740
1986	182	540	246,048	56,951	32,093	211,530
1987	178	520	254,004	57,958	63,404	246,235
1988	202	525	262,229	55,796	55,004	246,893

Table 4. Regression results of land values as a function of income measures in southwestern Minnesota.*

Model	C	CGFI	NCI	ANFI	AR(1)	adj.R2	DW
Income measures expressed per farm							
4.1	28.9 (0.52)	0.0055 (12.56)				.76	.18
4.2	-576 (-.24)	0.0054 (3.71)			.978 (14.18)	.96	.83
4.3	-32.9 (-.41)		0.026 (9.11)			.64	.38
4.4	858 (1.30)		0.002 (0.61)		.965 (26.72)	.94	.64
4.5	287 (2.98)			0.017 (3.90)		.23	.39
4.6	1234 (1.43)			-0.003 (-2.11)	.974 (30.96)	.95	.46
Income measures expressed per acre							
4.7	-304 (-9.13)	4.17 (28.16)				.95	.67
4.8	2169 (0.47)	2.21 (3.86)			.995 (16.38)	.98	1.74
4.9	-573 (-4.97)		20.67 (9.89)			.70	.76
4.10	-182 (-1.01)		1.97 (2.08)		1.08 (39.40)	.98	1.43
4.11	166 (1.41)			8.55 (3.39)		.20	.45
4.12	-125 (-0.52)			-1.33 (-3.76)	1.07 (48.63)	.98	.98

*The variables are defined as follows:
SWVAL - value of land in Southwest Minnesota per acre
GCFI - gross cash farm income
NCI - net cash farm income
ANFI - accrual net farm income
t-values are in parentheses.

NOTE: Due to a missing acreage value in 1983 the per acre models (4.7 - 4.12) were estimated with data from 1940 through 1982.

Table 5. Regression results of land prices from annual survey as a function of income measures in southwestern Minnesota.

Model	C	CGFI	NCI	ANFI	AR(1)	adj.R2	DW
5.1	-.96 (-.01)	0.006 (10.21)				.75	.24
5.2	139 (0.27)	0.004 (2.15)			.927 (11.21)	.94	.95
5.3	-20.7 (-.22)		0.027 (6.94)			.58	.47
5.4	1341 (1.50)		-0.002 (-0.41)		.960 (21.94)	.93	.61
5.5	471 (3.34)			0.013 (2.51)		.13	.30
5.6	1455 (1.64)			-0.003 (-1.75)	.963 (23.19)	.94	.55

Table 6. Autoregressive (AR), Moving Average (MA), and ARMA models of the southwest Minnesota value of land, twice differenced.

VARIABLE/ MODEL	6.1	6.2	6.3	6.4	6.5	6.6
C	-.03 (-.002)	-.31 (-.02)	4.22 (1.27)	3.94 (1.13)	3.92 (1.32)	3.85 (1.32)
MA(1)	-.30 (-1.83)	-.28 (-1.76)			.01 (.04)	
MA(2)	.10 (.62)					
MA(4)	-.44 (-2.59)	-.40 (-2.32)			.43 (2.09)	.44 (2.33)
MA(6)	-.34 (-1.85	-.30 (-1.64)			.64 (1.94)	.64 (2.23)
AR(1)			-.40 (-2.97)	-.37 (-2.79)	-.38 (-2.15)	-.38 (-3.20)
AR(2)			.44 (2.80)	.45 (2.87)	.28 (1.64)	.28 (1.71)
AR(4)			.18 (1.06)			
AR(6)			-.68 (-3.85)	-.59 (-3.80)	-.87 (-4.38)	-.87 (-4.62)
AR(9)			-2.91 (-5.37)	-2.64 (-5.49)	-2.43 (-5.37)	-2.43 (-5.58)
adjR^2	.18	.18	.47	.47	.57	.59
DW	2.06	2.09	2.05	2.27	1.99	1.97

Table 7. Land values as a function of lagged gross cash farm income, twice differenced, and an ARMA model.

VARIABLE/MODEL:	7.1	7.2	7.3	7.4
C	1.85 (0.18)	2.38 (.24)	-2.17 (-.39)	-2.36 (-.62)
GCFIDD	.003 (3.39)	.003 (4.46)	.003 (6.26)	.003 (7.08)
GCFIDD(-1)	.004 (4.62)	.004 (6.12)	.004 (8.10)	.004 (9.11)
GCFIDD(-2)	-.001 (-.86)			
GCFIDD(-3)	.003 (3.42)	.004 (5.12)	.004 (6.02)	.003 (6.46)
GCFIDD(-4)	-.003 (-2.66)	-.002 (-2.72)	-.002 (-2.37)	-.002 (-3.91)
GCFIDD(-6)	-.005 (-5.66)	-.005 (-5.94)	-.005 (-5.71)	-.005 (-7.82)
GCFIDD(-8)	.001 (.62)			
MA(4)			.07 (.29)	
MA(6)			.81 (2.01)	.90 (2.50)
AR(1)			.09 (.48)	
AR(2)			.05 (.26)	
AR(6)			-1.09 (-3.72)	-1.24 (-4.25)
AR(9)			.16 (.48)	
adjR^2	.74	.75	.83	.84
DW	1.60	1.54	2.22	2.19

Table 8. Land values as a function of lagged accrual net farm income, twice differenced, and an ARMA model.

VARIABLE/ MODEL	8.1	8.2	8.3	8.4	8.5	8.6	8.7
C	-.81 (-.10)	-476 (-.001)	-5.6 (-.37)	-.35 (-.02)	.63 (.03)	.05 (.01)	.75 (.17)
ANFIDD	.002 (1.61)	.0004 (.34)		-.001 (-1.51)	-.002 (-1.99	-.002 (-3.77)	-.002 (-5.57)
ANFIDD(-1)	.008 (8.06)	.007 (4.89)	.007 (13.99)	-.002 (1.45)	.002 (2.39)	.001 (1.75)	.001 (2.97)
ANFIDD(-2)	.008 (6.49)	.008 (4.01)	.008 (9.71)	-6.6D-05 (-.06)			
ANFIDD(-3)	.011 (6.38)	.012 (4.11)	.011 (9.85)				
ANFIDD(-4)	.013 (6.34)	.014 (4.96)	.014 (9.73)				
ANFIDD(-5)	.009 (4.60)	.010 (3.60)	.010 (6.66)				
ANFIDD(-6)	.005 (2.72)	.005 (2.12)	.006 (3.93)				
ANFIDD(-7)	.004 (2.22)	.004 (1.86)	.004 (3.38)	-.001 (-.77)			
ANFIDD(-8)	.002 (2.25)	.002 (1.62)	.002 (2.87)	.0002 (.12)			
MA(4)		-.56 (-.96)	-.89 (-4.03)			-.22 (-.90)	
MA(6)		-.45 (-.62)				.57 (1.22)	
AR(1)		.20 (.52)				.36 (2.23)	.28 (1.82)
AR(2)		-.12 (-.40)				-.50 (-2.95)	-.43 (-2.58)
AR(6)		.51 (.59)				-.37 (-.89)	
AR(9)		.41 (.79)	.46 (1.38)			-1.38 (-3.04)	-1.51 (-3.38)
adjR^2	.82	.84	.90	.41	.44	.65	.65
DW	1.94	2.05	1.97	1.29	1.25	2.17	2.34

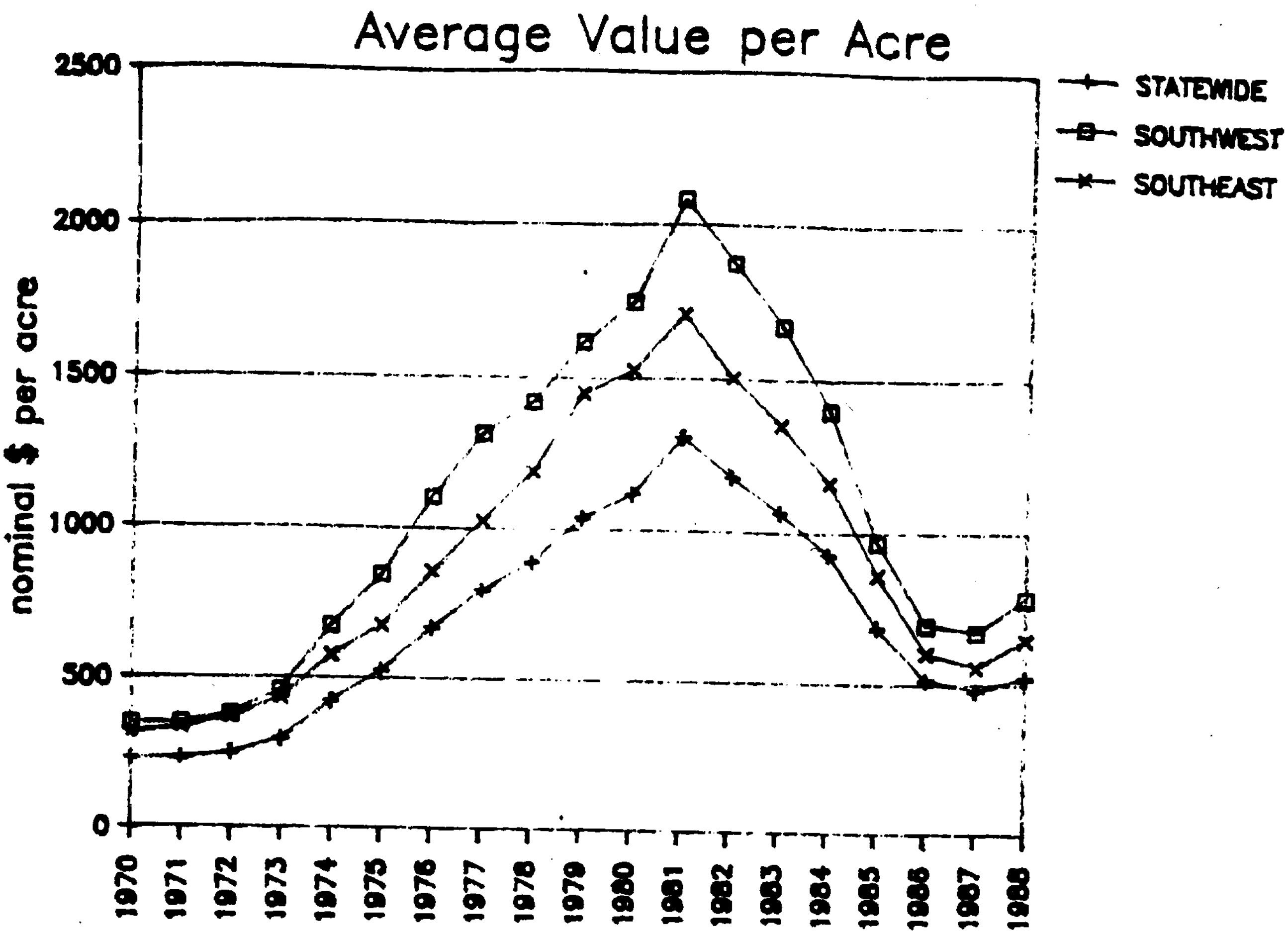

Figure 1. Estimated average value per acre of farmland in Minnesota: 1970-1988.

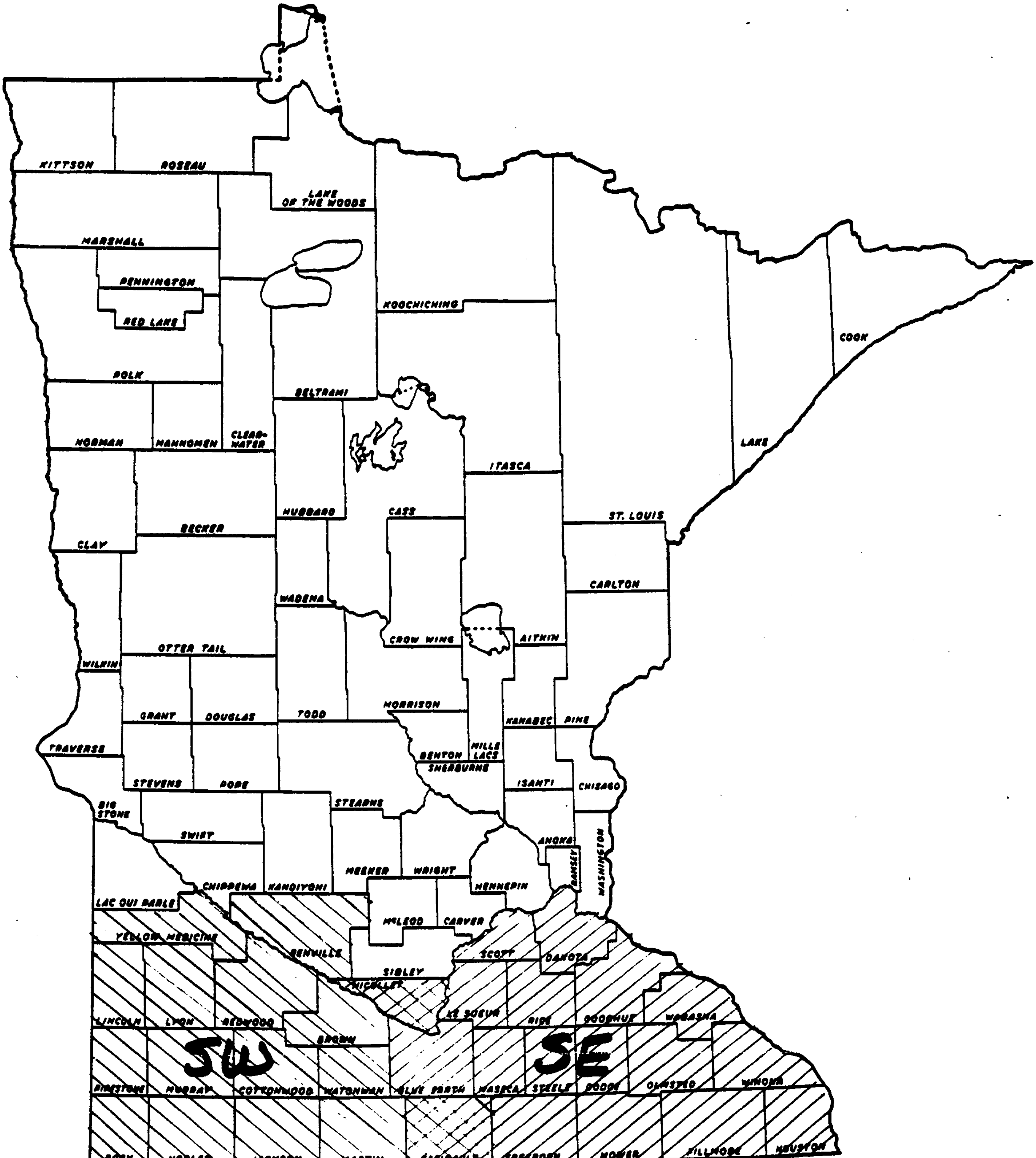

Figure 2. Counties in the Southeastern and Southwestern Minnesota Farm Business Management Associations.

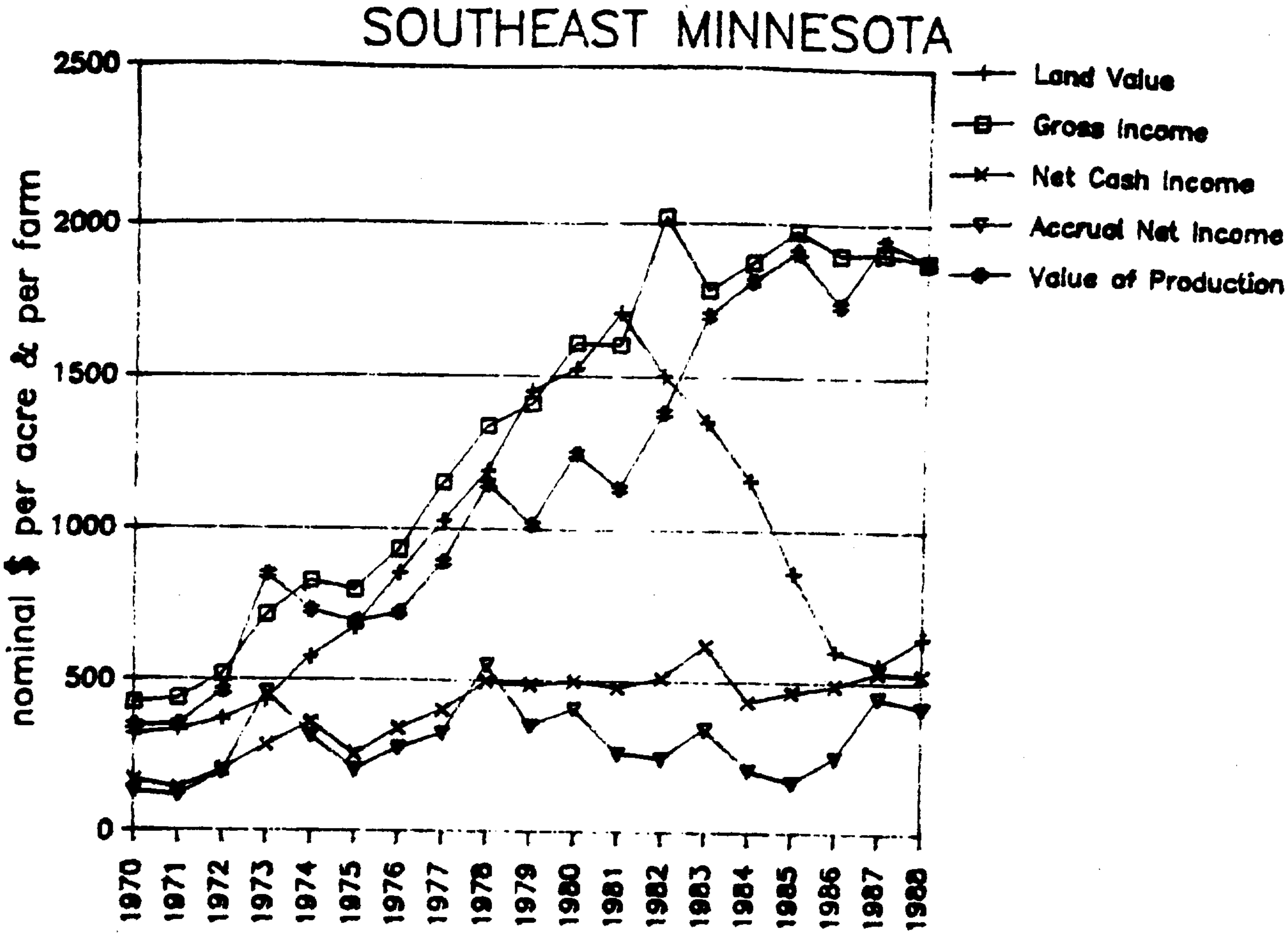

Figure 3a. Land value ($ per acre) and four income measures (hundred $ per farm) in Southeast Minnesota.

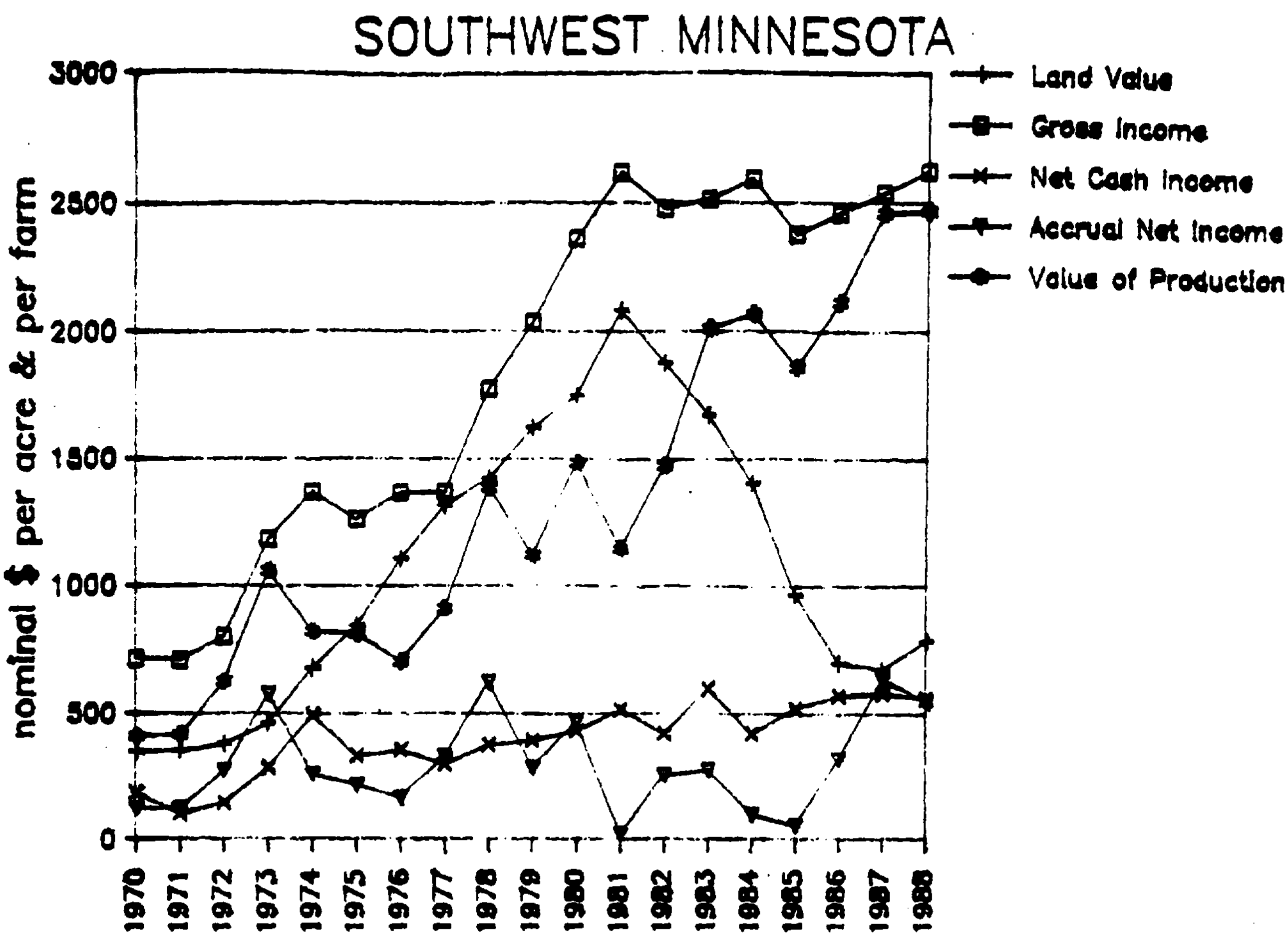

Figure 3b. Land value ($ per acre) and four income measures (hundred $ per farm) in Southwest Minnesota.

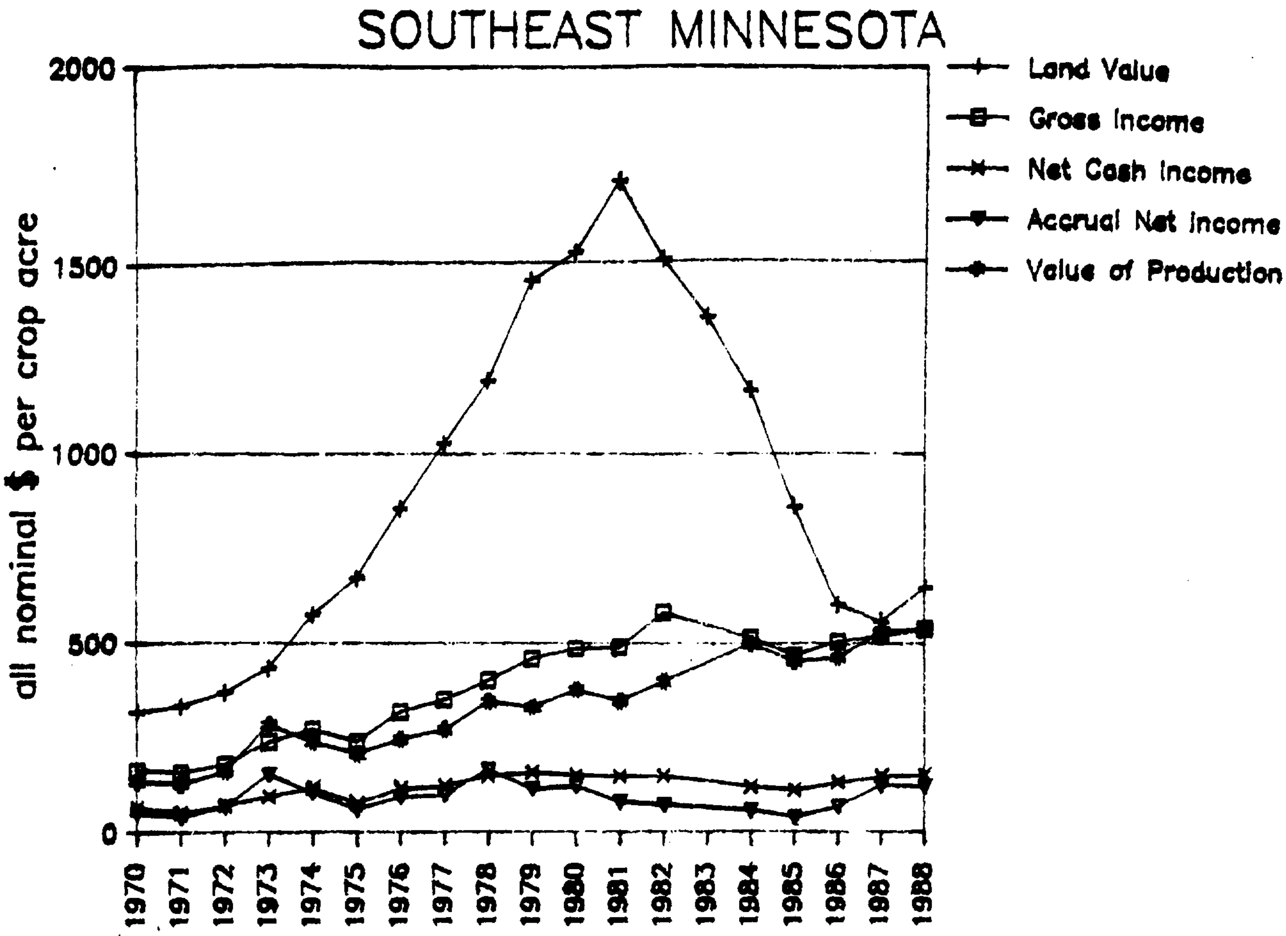

Figure 4a. Land value and income measures, all on a per acre basis, in Southeast Minnesota.

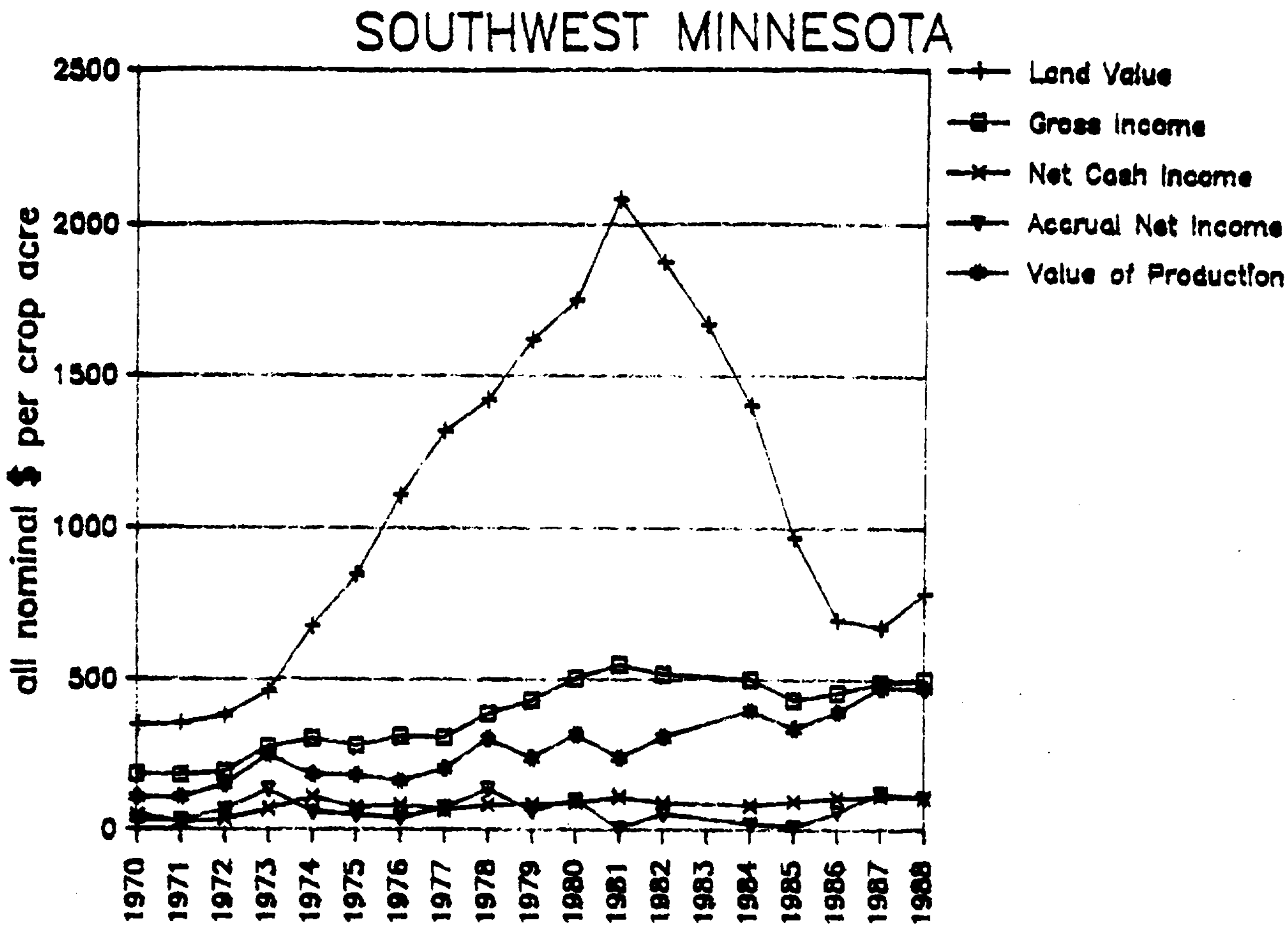

Figure 4b. Land value and income measures, all on a per acre basis, in Southwest Minnesota.

Figure 5. Autocorrelation and partial autocorrelation graphs, data range: 1942-1988.

a. SWVAL: value of land in Southwestern Minnesota

```
        Autocorrelations          Partial Autocorrelations          ac      pac
|          .   |*************|          .  |*************|  1  0.962   0.962
|          .   |************ |     ******|      .        |  2  0.889  -0.497
|          .   |**********   |       .***|      .        |  3  0.790  -0.212
|          .   |*********    |        .  *|     .        |  4  0.676  -0.075
|          .   |*******      |          . |     .        |  5  0.558  -0.001
|          .   |******       |          . |     .        |  6  0.443   0.028
|          .   |****         |          . |     .        |  7  0.336   0.002
|          .   |***.         |        . **|     .        |  8  0.234  -0.145
|          .   |** .         |          . |***.          |  9  0.152   0.214
|          .   |*  .         |          . |     .        | 10  0.088   0.022

 Q-Statistic (10 lags)  164.681              S.E. of Correlations  0.146
```

b. SWVALD: First difference of SWVAL

```
        Autocorrelations          Partial Autocorrelations          ac      pac
|          .   |*********    |          .  |*********    |  1  0.660   0.660
|          .   |******       |          . |     .        |  2  0.445   0.017
|          .   |** .         |       .***|      .        |  3  0.174  -0.224
|          .  *|   .         |        . **|     .        |  4 -0.054  -0.171
|          . **|   .         |          . |     .        |  5 -0.166  -0.006
|          .***|   .         |        .  *|     .        |  6 -0.239  -0.055
|          . **|   .         |          . |*    .        |  7 -0.170   0.100
|          ****|   .         |      *****|      .        |  8 -0.292  -0.361
|          ****|   .         |        . **|     .        |  9 -0.313  -0.120
|          ****|   .         |          . |*    .        | 10 -0.272   0.089

 Q-Statistic (10 lags)   48.789              S.E. of Correlations  0.146
```

Figure 5, continued.

5c. SWVDD: Second difference of SWVAL

```
==========================================================================
        Autocorrelations          Partial Autocorrelations      ac     pac
==========================================================================
|         . **|   .        |         . **|   .       |  1 -0.162 -0.162
|         .   |** .        |         .   |*  .       |  2  0.132  0.108
|         .   |   .        |         .   |   .       |  3 -0.035  0.002
|         .***|   .        |         .***|   .       |  4 -0.201 -0.229
|         .  *|   .        |         . **|   .       |  5 -0.070 -0.140
|         .***|   .        |         .***|   .       |  6 -0.211 -0.210
|         .   |** .        |         .   |** .       |  7  0.186  0.148
|         .  *|   .        |         .  *|   .       |  8 -0.115 -0.075
|         .  *|   .        |         ****|   .       |  9 -0.108 -0.280
|         .  *|   .        |         .***|   .       | 10 -0.043 -0.231
==========================================================================
 Q-Statistic (10 lags)    9.213             S.E. of Correlations   0.146
==========================================================================
```

Figure 6. Crosscorrelations of land values with income measures, data range 1942-1988.

6a. SWVALDD (Southwest value of land, twice differenced) with GCFIDD (gross cash farm income, twice differenced)

```
           COR(SWVDD,GCFIDD(-i))         i   lag
|         .   |*****        |  0  0.387
|         .   |***.         |  1  0.200
|         .***|   .         |  2 -0.244
|         .   |******       |  3  0.457
|        *****|   .         |  4 -0.388
|         .  *|   .         |  5 -0.047
|         ****|   .         |  6 -0.287
|         .   |   .         |  7  0.038
|         .   |****         |  8  0.301
|         . **|   .         |  9 -0.131
|         .   |*  .         | 10  0.083
                S.E. of Correlations  0.146
```

6b. SWVDD (Southwest value of land, twice differenced) with ANFIDD (accural net farm income, twice differenced)

```
           COR(SWVDD,ANFIDD(-i))         i   lag
|     ********|   .         |  0 -0.608
|         .   |********     |  1  0.614
|        *****|   .         |  2 -0.361
|         .   |***.         |  3  0.193
|         .   |** .         |  4  0.142
|         . **|   .         |  5 -0.191
|         .   |***.         |  6  0.196
|         ****|   .         |  7 -0.334
|         .   |***.         |  8  0.243
|         .  *|   .         |  9 -0.089
|         .   |   .         | 10 -0.015
                S.E. of Correlations  0.146
```

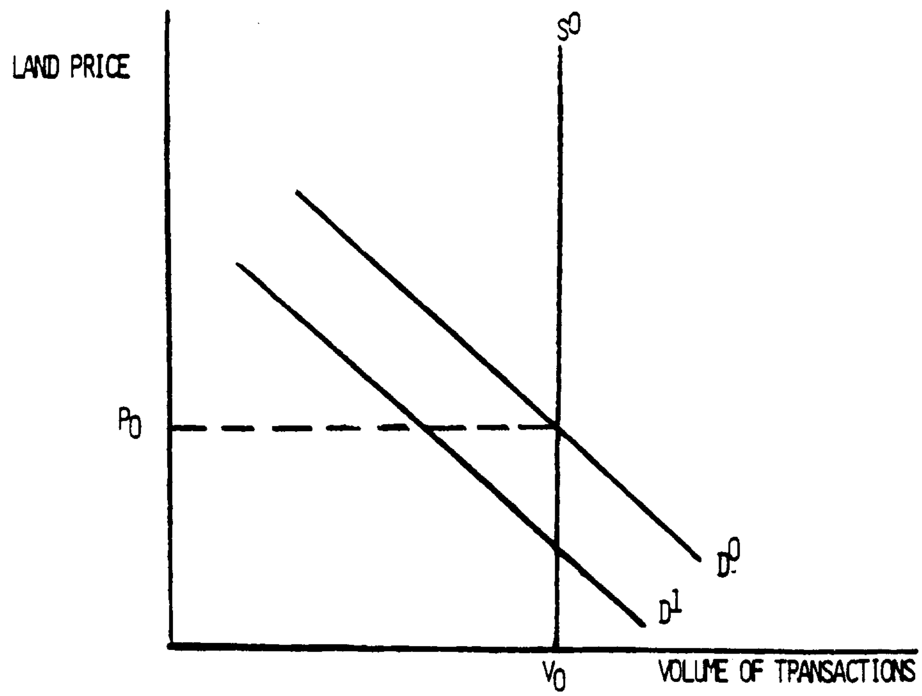

Figure 7. The traditional land pricing model with a fixed supply of land.

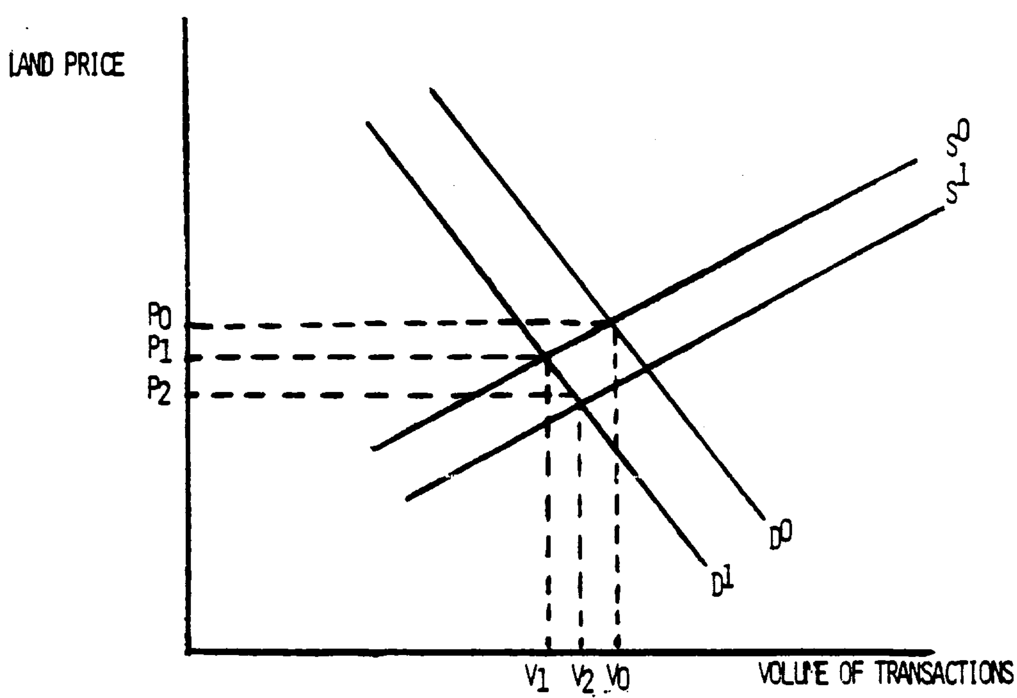

Figure 8. Land pricing model with a variable supply of land.

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CERTAINTY EQUIVALENT PRICES AND PRODUCER WELFARE UNDER PRICE UNCERTAINTY

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Abstract

Producer welfare indices under price uncertainty are derived using the concept of certainty equivalent prices. In this approach the marginal cost function is used instead of the *ex-ante* supply function; the effects of uncertainty and risk preference are captured by certainty equivalent prices. Implications for welfare evaluation are discussed.

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CERTAINTY EQUIVALENT PRICES AND PRODUCER WELFARE UNDER PRICE UNCERTAINTY

1. Introduction

Economists have long recognized the importance of uncertainty and risk aversion in the behavior of entrepreneurs. A new body of literature evolved in the 1970s around the works of Sandmo [1971] and Leland [1972] and augmented microeconomics by introducing the theory of firm decision making under uncertainty. The literature has proliferated substantially since these early works, and recent studies incorporate multi product, multi risk and multi period considerations (see e.g., Hey [1979], Just *et al.* [1982] and Newbery and Stiglitz [1981]). Less attention has been given to the welfare implications of choices made by risk averse producers. Only recently have the welfare consequences of the Sandmo-Leland framework become the focus of a growing literature (Chavas and Pope [1981], Pope *et al.* [1983], Pope and Chavas [1985], Larson [1988]). Particular attention has been given to the extension of welfare measures to situations of risk aversion and uncertainty and to the development of practical means of approximating these measures. Compensating Variation (CV), Equivalent Variation (EV) and Certainty (money) Equivalent (CE) have been the three indices considered for measuring producer welfare under uncertainty. (Section 2 provides a brief presentation of these indices.) The main tool used to approximate these measures has been the producer surplus calculated from the *ex-ante* output supply and input demand functions.

Pope and Chavas [1971], using Willig's approach [1976], show that producer surplus can be used "without apology" instead of EV and CV. Larson [1988] offers a procedure, in the spirit of that suggested by Hausman [1981], which evaluates these indices exactly. Both approaches rely upon the *ex-ante* output supply and input demand functions. The evaluation of these functions in actual practice is in many case cumbersome, requiring data which are hard to obtain; thus applications rarely are found.

A procedure to evaluating the producer welfare indices without the need of the *ex-ante* supply and demand functions may therefore be useful. In this paper we describe such a procedure. It relies upon the concept of the Certainty Equivalent of Price (CEP) and uses the purely technological relation of the marginal cost curve instead of the *ex-ante* supply function. By using CEP, we derive (in Section 3) the three welfare indices as the profits (abstracting from fixed costs) that would prevail under certainty at different levels of the CEP. Implications for welfare evaluation in practice are discussed.

2. Welfare Measures

Consider a risk averse supplier of a single product who faces uncertainty on product price.[1] The producer maximizes expected utility, where the utility function $U(\cdot)$ is defined on wealth and satisfies $U'>0$ and $U''<0$. Wealth is composed of initial wealth, W_o, and the operating profit $PY-C(Y;\alpha)$, where P is the output price, Y is output supplied, $C(\cdot)$ is the variable cost function generated by some underlying production technology and α is a parameter vector characterizing the production technology (unless needed explicitly, α will be suppressed from the arguments of C). The uncertainty is represented by a (subjective) cumulative distribution function on the output price. This distribution function is assumed to be uniquely defined by the moments vector $\theta=(\mu,\sigma,\ldots)$, where $(\mu,\sigma,\ldots)$ represents the mean, standard deviation and higher central moments of output price.[2]

The firm is a taker of a price distribution characterized by the vector θ. The *ex-ante* supply function, $Y(\theta,W_o)$, is the supply level that maximizes the expected utility $E\{U(PY-C(Y)+W_o)\}$. Plugging $Y(\theta,W_o)$ into the maximand yields the indirect expected utility of profit

$$V(\theta,W_o) = E\{U(W(\theta,W_o)+W_o)\}, \qquad (2.1)$$

where

$$W(\theta,W_o) = PY(\theta,W_o) - C(Y(\theta,W_o)). \qquad (2.2)$$

$V(\theta,W_o)$ is a non-monetary measure of the well-being of a producer endowed with initial wealth W_o which operates under output price uncertainty characterized by θ. The associated monetary measure, indicated by $\hat{W}(\theta,W_o)$, is the money income that leaves the producer indifferent to receiving it with certainty or having the random income $W(\theta,W_o)$. Thus $\hat{W}(\theta,W_o)$ is the lowest certain income the producer would be willing to receive instead of the prevailing uncertain income $W(\cdot)$; it satisfies

$$U(\hat{W}(\theta,W_o)+W_o) = V(\theta,W_o). \qquad (2.3)$$

Suppose a change in the price distribution, indicated by a move $\theta^1 \longrightarrow \theta^2$, occurs. The resulting change in producer welfare is $V(\theta^2,W_o)-V(\theta^1,W_o)$. In view of the definition of $\hat{W}(\cdot)$, an natural monetary measure of this welfare change would be the Certainty (money) Equivalent (CE) index

$$CE = \hat{W}(\theta^2,W_o) - \hat{W}(\theta^1,W_o). \qquad (2.4)$$

Two other monetary indices have been considered in the literature; they are the Compensating Variation (CV) and the Equivalent Variation (EV) defined from:

$$V(\theta^1,W_o+EV) = V(\theta^2,W_o), \qquad (2.5)$$

$$V(\theta^2,W_o-CV) = V(\theta^1,W_o). \qquad (2.6)$$

Figure 1 provides a graphical representation of producer surplus (S), CE and CV in the μ-Y plan, with σ and higher moments of output price held constant (since CV and EV are parallel concepts, only CV is considered). The curve indicated by Y is the *ex-ante* supply defined above. The curve labeled Y_c is the *ex-ante* supply when the producer's initial wealth is compensated to keep him or her as well off as under regime θ^1. The curve indicated by Y_h is the derivative of $\hat{W}(\cdot)$ with respect to μ , and lies to the right of the *ex-ante* supply, provided that decreasing absolute risk aversion prevails (see e.g., Pope and Chavas). The three indices CV, S and CE are given by the areas

$\mu^2 ae\mu^1$, $\mu^2 be\mu^1$ and $\mu^2 cd\mu^1$, respectively. The producer that generates the curves depicted in Figure 1 exhibits decreasing absolute risk aversion with respect to wealth. Under constant absolute risk aversion, the three curves and their corresponding welfare indices coincide.[3]

Figure 1

3. Certainty Equivalent Prices and the Three Welfare Measures

The concept of Certainty Equivalent Price (CEP) is now used to derive alternative representations of the three welfare indices. The underlying idea is simple. Recalling that producer welfare under certainty (i.e., profit) is measured by the area to the left of the Marginal Cost (MC) curve and below the output price, we will show that the three welfare measures CE, EV and CV are obtained as areas to the left of MC and between appropriate CEP levels.

The CEP, denoted by $\hat{P}(\theta, W_o)$, is the least certain price that a risk averse producer, endowed with initial wealth W_o, would be willing to receive instead of the random price distributed according to θ.[4] Formally, $\hat{P}(\theta, W_o)$ satisfies:

$$\hat{P}(\theta, W_o)\cdot Q[\hat{P}(\theta, W_o)] - C(Q[\hat{P}(\theta, W_o)]) = \hat{W}(\theta, W_o), \tag{3.1}$$

where $Q[\cdot]$ is the supply under certainty determined by equating price to marginal cost and $\hat{W}(\theta, W_o)$ is defined in equation (2.3).

It follows directly from (3.1) and (2.4) that

$$CE = \hat{P}(\theta^2, W_o)\cdot Q[\hat{P}(\theta^2, W_o)] - C(Q[\hat{P}(\theta^2, W_o)]) - \{\hat{P}(\theta^1, W_o)\cdot Q[\hat{P}(\theta^1, W_o)] - C(Q[\hat{P}(\theta^1, W_o)])\}. \tag{3.2}$$

Furthermore, EV and CV can now be represented in terms of CEP as:

$$EV = \hat{P}(\theta^2, W_o)\cdot Q[\hat{P}(\theta^2, W_o)] - C(Q[\hat{P}(\theta^2, W_o)]) - \{\hat{P}(\theta^1, W_o+EV)\cdot Q[\hat{P}(\theta^1, W_o+EV)] - C(Q[\hat{P}(\theta^1, W_o+EV)])\} \tag{3.3}$$

and

$$CV = \hat{P}(\theta^2,W_o-CV)\cdot Q[\hat{P}(\theta^2,W_o-CV)] - C(Q[\hat{P}(\theta^2,W_o-CV)]) - \{\hat{P}(\theta^1,W_o)\cdot Q[\hat{P}(\theta^1,W_o)] - C(Q[\hat{P}(\theta^1,W_o)])\}. \quad (3.4)$$

To verify (3.3), note that the first term on its right hand side equals $\hat{W}(\theta^2,W_o)$, which is also equal to $U^{-1}(V(\theta^2,W_o))-W_o$ [cf. equation (2.3)]. The second term equals $\hat{W}(\theta^1,W_o+EV) = U^{-1}(V(\theta^1,W_o+EV))-W_o-EV$. But EV satisfies $V(\theta^1,W_o+EV)=V(\theta^2,W_o)$ [cf. (2.5)], which implies (3.3). A similar argument can be used to verify (3.4).

From (3.2)-(3.4) it directly follows that the three welfare indices are obtained as areas to the left of the MC curve and between appropriate CEP levels:

$$CE = \int_{\hat{P}(\theta^1,W_o)}^{\hat{P}(\theta^2,W_o)} Q[x]dx \quad , \quad (3.5)$$

$$EV = \int_{\hat{P}(\theta^1,W_o+EV)}^{\hat{P}(\theta^2,W_o)} Q[x]dx \quad (3.6)$$

and

$$CV = \int_{\hat{P}(\theta^1,W_o)}^{\hat{P}(\theta^2,W_o-CV)} Q[x]dx \quad . \quad (3.7)$$

To verify (3.5) note, from (3.2), that CE is the difference between the quasi-rents evaluated at the CEP levels $\hat{P}(\theta^2,W_o)$ and $\hat{P}(\theta^1,W_o)$. This difference is merely the area to the left of the MC curve between these two CEP levels. In a similar manner, (3.6) and (3.7) follow from (3.3) and (3.4). A graphical illustration is presented in Figure 2.

Figure 2

Which of the three welfare indices CE, CV or EV is the appropriate one to use in any given situation is still an open question and we shall not dwell on this issue here. We only note that all three satisfy the welfare criterion (expressed in terms of CE): *regime θ^2 is preferred or indifferent to regime θ^1 if and only if $CE \geq 0$.* This follows directly from the strict monotonicity of

U(·) and equations (2.3) and (2.4); where the preference relation over the uncertain regimes θ is represented by the indirect utility function V(·).

Evaluating the CE index appears to be simpler than the task of evaluating the other, variational indices. This is so because the CE does not entail (hypothetical) income compensations. All three indices require information on the MC curve, which is a technological relationship independent of risk preferences and uncertainly. Evaluating EV and CV requires, in addition, knowledge of the behavior of the CEP function over an interval of income compensation levels. From representation (3.6), the EV measure associated with θ^1 and θ^2 requires the knowledge of $\hat{P}(\theta^2, W_o)$ and of $\hat{P}(\theta^1, W_o+EV)$ for various levels of EV. Evaluating CE, On the other hand, requires the knowledge of just two points of the CEP function, $\hat{P}(\theta^1, W_o)$ and $\hat{P}(\theta^2, W_o)$, which are evaluated at the uncompensated initial wealth W_o (cf.equation (3.5)). Obviously, it is easier to obtain two CEP points evaluated at the actual initial wealth rather than a continuum of points defined over an interval of (hypothetically) compensated income levels.

With decreasing absolute risk aversion, implying that the CEP is positively related to wealth (as the initial wealth increases producers are less bothered by the uncertainty and will demand a higher [certain] price to get rid of it), it is apparent from Figure 2 that CE exceeds both CV and EV. With constant absolute risk aversion, i.e., without wealth effects, the three indices coincide (simply note that the limits of integration in (3.5)-(3.7) are the same).

4. Implications

Applying the present approach in practice requires information on i) the marginal cost (MC) curve and ii) some CEP levels. The MC curve depends on the production technology and can be evaluated from engineering data. The effects of uncertainty and risk preference are captured by the CEP. Obtaining the required CEP information is more problematic because there exists no market mechanism through which data on this variable can be observed. One must resort then to indirect data. In cases where producers are free to choose the price distribution under which to operate, it is possible to use the observable discrete choices of the uncertain regime in order to obtain the required CEP information. Such is the case, for instance, when producers must decide on whether to participate in an agricultural commodity program. A participation decision entails a certain price distribution (which depends on the program's provisions) whereas the decision not to participate entails another price distribution (determined mainly by market conditions). Another example is where a choice must be made on a single product to produce among several possible products. The production technologies are perfectly known but the demand for each product is uncertain and this uncertainty varies across products.

As an illustration, suppose two price distributions, characterized by the moment vectors θ^1 and θ^2, are available to choose from. Evaluating the CE index of the welfare difference between the two uncertain regimes requires knowledge of $\hat{P}(\theta^j, W_o)$, $j=1,2$. Suppose the form of the CEP function $\hat{P}(\cdot)$ is known[5]. This function depends on its arguments (θ, W and possibly socioeconomic characteristics of the producer) via a set of unknown parameters β. We assume the production technology is known (i.e., its form is specified and its parameters are estimated from available data) so that the cost function $C(\cdot)$ and the inverse marginal cost function $Q[\cdot]$ are given. Thus the certainty equivalent income function (cf. equation (3.1))

$$\hat{W}(\theta, W_o;\beta) = \hat{P}(\theta, W_o;\beta)Q[\hat{P}(\theta, W_o;\beta)] - C(Q[\hat{P}(\theta, W_o;\beta)])$$

is known up to the parameter vector β. We seek to estimate β.

The decision problem facing producers is that of a binary choice between θ^1 and θ^2. Regime 1 is chosen if $V(\theta^1, W_o) > V(\theta^2, W_o)$ or equivalently, using equation (2.3), if $\hat{W}(\theta^1, W_o) > \hat{W}(\theta^2, W_o)$. Regime 2 is chosen otherwise. Taking account of measurement (and possibly of specification) errors and letting ϵ represent these errors, the problem can be formulated in terms of a non-linear discrete choice model:

$$d = \begin{cases} 1 & \text{if } \hat{W}(\theta^1, W_o;\beta) - \hat{W}(\theta^2, W_o;\beta) + \epsilon > 0 \\ 0 & \text{otherwise} \end{cases} .$$

Given data on the discrete choices (d), on wealth (W_o) and possibly on other socioeconomic attributes of a sample of growers, and given θ^1 and θ^2, the parameter vector β can be estimated up to a normalization scale (the variance of the error term ϵ). Consequently, CE can be estimated according to equation (3.5). Furthermore, if estimates are available of the wealth effect in the CEP function (due to variation in wealth levels across individuals), the CV and EV indices can be calculated as the roots of equations (3.6) and (3.7), respectively.

Even when this indirect approach is not feasible (perhaps because data on related decisions are not available), there is still another approach, a direct one, that is worth considering; namely, eliciting the required CEP information via interviews. Experimental methods to elicit utility information have a long history in decision theories (see e.g., Becker, DeGroot and Marschak [1964]). A related literature, dealing with the valuation of public goods and other extra market benefits, appears under the heading of "contingent valuation methods" (Mithchel and Carson [1989]).

If this direct approach is suggested, one may wonder whether the present analysis is at all useful, since it is (in principle) possible to elicit information on income compensations and thereby to obtain the EV and CV directly. A closer look, however, reveals an important difference. The type of information needed to calculate CE (cf. eq. (3.5)) concerns *prices* (i.e., certainty equivalent prices) and prices are different entities than (compensated) incomes. Whether the task of eliciting price information is easier than that of eliciting income information (say, because people use to think in terms of prices) is an issue that must be resolved empirically. The important thing to note is that the two tasks are different.

5. Summary

The three welfare measures of a risk averse producer under price uncertainty --the Certainty Equivalent (CE), the Compensating Variation (CV) and the Equivalent Variation (EV)-- are derived using the concept of Certainty Equivalent Price (CEP). In this approach the technological marginal cost function (the supply function under certainty) is used instead of the *ex-ante* supply function. The effects of uncertainty and risk aversion are captured by the CEP. Implications for the use of this approach in practice are discussed. It is found that evaluating the CE is particularly simple in the sense of requiring the least information.

The proposed approach differ from other existing methods in that it relies on the CEP rather than on the *ex-ante* supply function. Its implementation, therefore, requires different type of information. Whether this is an advantage or disadvantage in any given set of circumstances must be determined empirically, depending on the available data.

Appendix A. Uncertain Input Prices

Suppose output and input prices are uncertain. Let $q=(p,r)$ be the 1+k vector of random output and input prices whose distribution is characterized by the moment vector θ. Let $x(\theta,W_o)$ be the k by 1 vector of *ex-ante* input demand functions defined from $\underset{x}{Max}\ E\{U(py(x)-r\cdot x+W_o)\}$, where the expectation is taken with respect to the joint distribution of all prices and $y(x)$ is the production function. The indirect utility of profit is defined, analogously to equation (2.1), as $V(\theta,W_o) = E\{U(py(x(\theta,W_o))-r\cdot x(\theta,W_o)+W_o)\}$ and the certainty equivalent income $\hat{W}(\theta,W_o)$ is as defined in equation (2.3). Given $V(\cdot)$ and $\hat{W}(\cdot)$, the three welfare indices are as defined in equations (2.4)-(2.6).

Let the k functions $x[\cdot]$ represent the input demand under certainty. That is, for any given price vector, say $q_o = (p_o,r_o)$, $x[q_o]$ satisfies $Dy(x[q_o])=r_o/p_o$, where $Dy(\cdot)$ is the vector of the first derivatives of y. The certainty equivalent price vector $\hat{q} = (\hat{p}(\theta,W_o),\hat{r}(\theta,W_o))$ can now be defined as the solution to the k+1 equations:

$$\hat{p}y(x[\hat{q}]) - \hat{r}\cdot x[\hat{q}] + W_o = \hat{W}$$

$$Dy(x[\hat{q}]) = \hat{r}/\hat{p} .$$

Suppose a change in the uncertainty, indicated by a move $\theta^1 \rightarrow \theta^2$, occurs. Let $\hat{q}(\theta^j,Z) = (\hat{p}(\theta^j,Z),\hat{r}(\theta^j,Z))$ be the CEP under regime θ^j, j=1,2, with Z indicating the compensated initial wealth. Let $QR(\hat{q}) = \hat{p}y(x[\hat{q}]) - \hat{r}\cdot x[\hat{q}]$ represent the quasi-rent under certainty associated with the (certain) price vector $\hat{q}$. Then, using the derivation of Section 3, it is straightforward to verify that:

$$CE = QR(\hat{q}(\theta^2,W_o)) - QR(\hat{q}(\theta^1,W_o)),$$

$$EV = QR(\hat{q}(\theta^2,W_o)) - QR(\hat{q}(\theta^1,W_o+EV)),$$

$$CV = QR(\hat{q}(\theta^2,W_o-CV)) - QR(\hat{q}(\theta^1,W_o)).$$

Consider the special case where only one price is uncertain, say that of the first input, with the output price and the rest of the input prices given at a known level. Using Hotelling's lemma it can be verified that the three welfare indices are obtained as areas to the left of the first input demand function and between appropriate levels of the first input CEP:

$$CE = \int_{\hat{r}_1(\theta^1, W_o)}^{\hat{r}_1(\theta^2, W_o)} x_1[s]ds, \quad EV = \int_{\hat{r}_1(\theta^1, W_o+EV)}^{\hat{r}_1(\theta^2, W_o)} x_1[s]ds \quad \text{and } CV = \int_{\hat{r}_1(\theta^1, W_o)}^{\hat{r}_1(\theta^2, W_o-CV)} x_1[s]ds ,$$

where $x_1[s]$ is the demand for the first input as a function of the first input's price, s, given that all other prices are at their fixed known level.

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Figure Captions

Figure 1. CV = area $\mu^2 ae\mu^1$; S = area $\mu^2 be\mu^1$; CE = area $\mu^2 cd\mu^1$.

Figure 2. CE = area EADH; EV = area EACG; CV = area FBDH.

Footnotes

[1]This simple case is considered for the sake of presentation clarity. The analysis extends to cases involving also input price uncertainty. We outline this case in the Appendix.

[2]The condition for the moments of a random variable to define a unique distribution function can be found in Rao [1965, p. 86].

[3]It is obvious that in the absence of wealth effect, i.e., under constant absolute risk aversion, $Y_c = Y(\theta, W_o)$. To see that $Y_h = Y(\theta, W_o)$ in this case, note that $Y(\theta, W_o)$ is the supply level that maximizes $E\{U(PY - C(Y) + W_o)\}$ and satisfies the first order condition: $E\{U'(W(\theta, W_o)) \cdot [P - C'(Y(\theta, W_o))]\} = 0$. By differentiating equations (2.2) and (2.3) with respect to μ and using the above condition, we obtain $\partial \hat{W}(\theta, W_o)/\partial\mu = Y(\theta, W_o) \cdot H(\theta, W_o) = Y_h$, where $H(\theta, W_o) = E\{U'(W(\theta, W_o))\}/U'(\hat{W}(\theta, W_o))$. Now constant absolute risk aversion implies exponential utility. Without loss of generality, let $U(W) = 1 - e^{-AW}$, A being the absolute risk coefficient, and define M as the moment generating function of W (assumed to exists). Thus $E\{U(W)\} = 1 - M(-A)$. From $U(\hat{W}) = E\{U(W)\}$ it follows that $\hat{W} = -\log\{M(-A)\}/A$. Likewise $E\{U'(W)\} = A \cdot E\{e^{-AW}\} = A \cdot M(-A)$, and $U'(\hat{W}) = A \cdot e^{-A\hat{W}} = A \cdot M(-A)$. Recalling the definition of H above, we obtain $H(\cdot) = 1$.

[4]Newbery and Stiglitz [1981, p. 59] denote this price the *utility certainty equivalent price*, as opposed to the *action certainty equivalent price*. The latter is the price that under certainty would result in the supply level being equal to the *ex-ante* supply $Y(\theta, W_o)$.

[5]This can be achieved directly by specifying the utility function and the output price distribution and proceeding along the definitions of $\hat{W}(\cdot)$ and $\hat{P}(\cdot)$ [cf. equations (2.3) and (3.1)], or indirectly by specifying a form of $\hat{P}(\cdot)$ which is consistent with some underlying utility function and output price distribution.

FIGURE 1

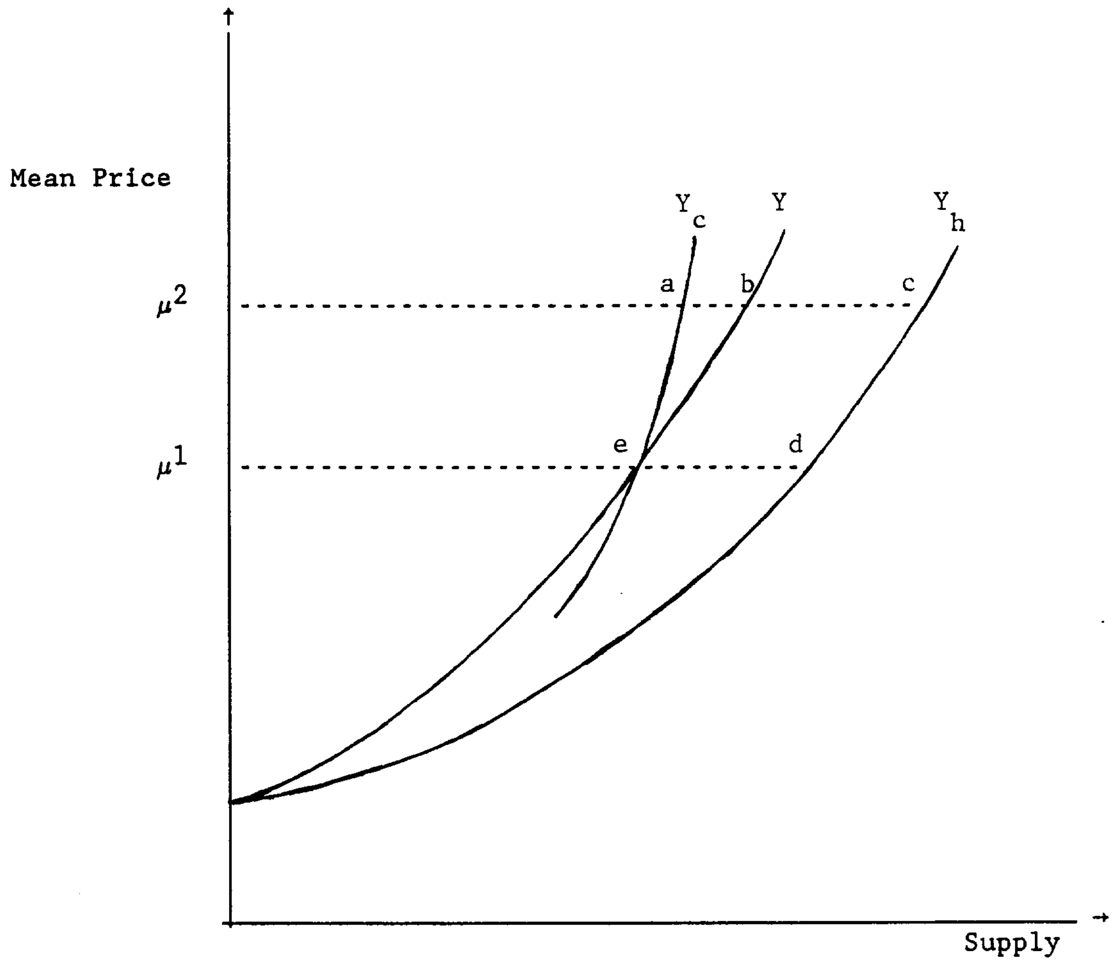
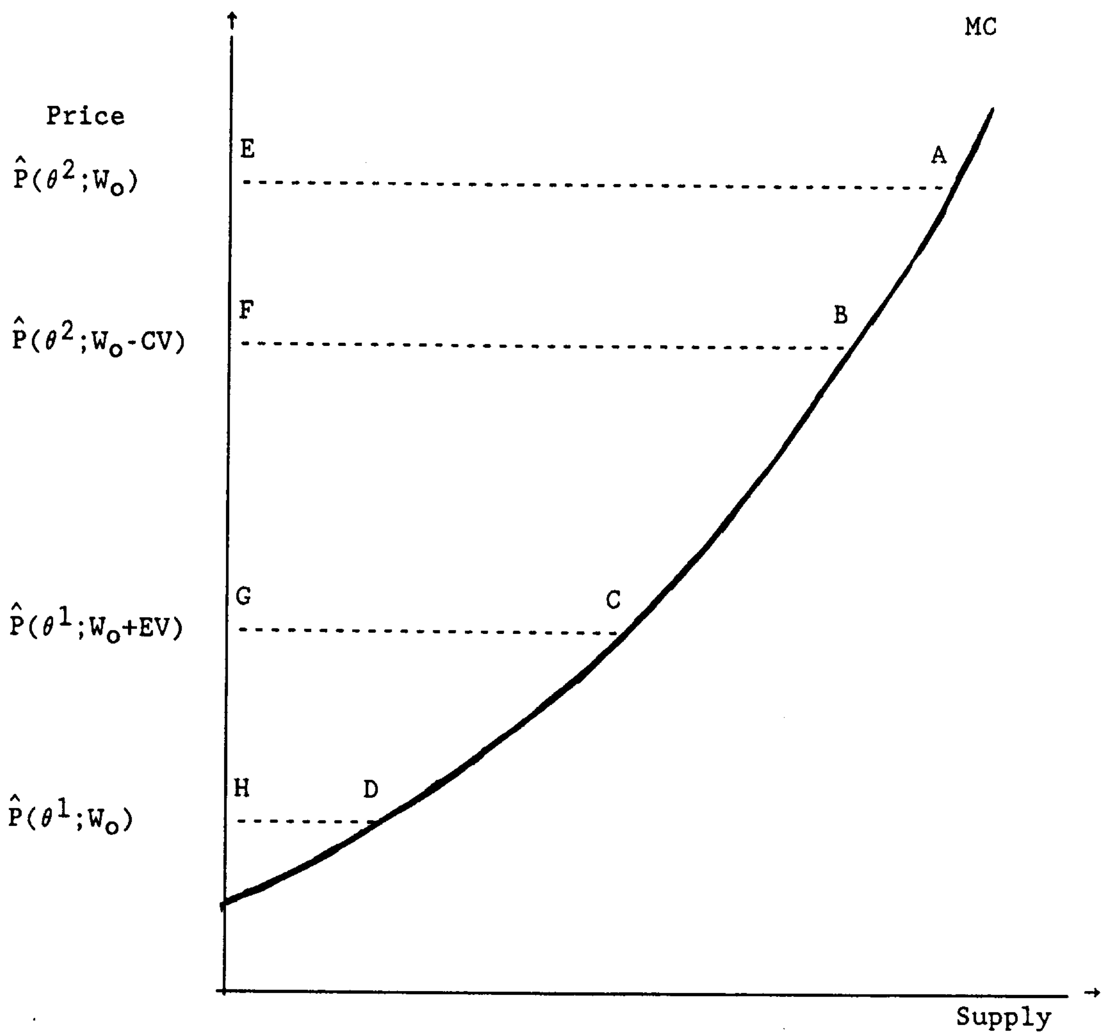


FIGURE 2


MC
Price
$\hat{P}(\theta^2;W_o)$
E
A
$\hat{P}(\theta^2;W_o\text{-}CV)$
F
B
$\hat{P}(\theta^1;W_o+EV)$
G
C
$\hat{P}(\theta^1;W_o)$
H
D
Supply