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An economic perspective on Iowa farm diversification in the twentieth century

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An economic perspective on Iowa farm diversification in the Twentieth Century

by

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CHAPTER 1. INTRODUCTION

The evolution of Iowa agriculture has been nothing short of remarkable. Consider the subsistence farm of the "sod-busting" days. It was a small, labor-intensive unit with a high degree of integration among a well-diversified mix of enterprises. The farm's purpose as an economic unit was to directly provide food and resources for family living. Compare that with today's Iowa farm. It is highly-leveraged, capital-intensive, inextricably linked to factor and commodity markets, produces a specialized product mix, and covers hundreds or thousands of acres. As an economic unit, its purpose is to produce a few bulk commodities at the lowest possible cost of production. The change could not be more striking.

Different terms have been applied to this evolution. "Industrialization" and "commercialization" are the most prevalent. Regardless of the term used, the change is an inevitable, irreversible consequence of the growth and development of the United States economy (McCalla and Valdés, 1999). It is interesting to examine how the individual components of the agricultural system have changed as the system itself changes. At the farm level, these include size, ownership structure, profitability, labor, technology, debt level, and off-farm work, among others. These issues have received extensive treatment from economic researchers. An issue that seems to have received less attention is change in diversification of farm enterprises over time.

Diversification must be couched within a specific context to make measurement and discussion of it meaningful. Diversification can be defined as a characteristic of a region, meaning the number of different industries that serve as major employers in that region; or it can be defined for a specific firm, meaning the number of products or services offered to the market (Kulshreshtha, 1989). This discussion places it at the firm level, or more specifically, at the Iowa farm firm level.

Even at the firm level, diversification can take on many different definitions. In the United Kingdom, farm diversification is usually meant as any economic activity carried out by the farm household (Gasson, 1988; Shucksmith *et al*, 1989; Evans and Ilbery, 1993; Shaw and Hale, 1996). It can include agricultural production, nonagricultural services offered on the farm (lodging, hunting, fishing, tours, etc.), work performed on other farms (custom hiring), and nonagricultural work performed off the farm. In these forms, diversification is synonymous with the terms "part-time farming" and "pluriactivity". When defined in such a way, the discussion is usually centered on rural development, farm structure, and the viability of the family farm. This thesis is not concerned with pluriactivity, but is confined to agricultural activity performed on the farm.

The definition must still be narrowed. It can take on an operational meaning. Kerr (1989) does not consider a firm or region to be diversified unless multiple enterprises reduce the income variability of that firm or region. It is more than simply a function of the number of enterprises undertaken or products produced. However, the focus here is to examine changes in the mix of farm enterprises. Reduction of income variability is a possible factor in the change, but does not enter into the definition.

One further refinement is necessary to obtain a working definition useful for this thesis. Diversity can mean investment in assets as well as activities. A farmer's diversified portfolio might include on-farm production enterprises, stocks and bonds, and a share in a joint venture such as an ethanol processing plant (Brown, 1989). Agricultural diversification can certainly be discussed in terms of capturing more value from the farm-gate-to-retail-store supply chain (Klein and Chase-Wilde, 1989). Value-added agriculture is often cited as the key to rural development in the United States. Again, this study is not concerned with off-farm investment.

One is now left with a definition of diversification: the distribution of resources among agricultural production enterprises on the farm. This is what will be measured and discussed. The term "enterprise" means the production of a specific crop (corn, soybeans, alfalfa, etc.), a group of products (dairy, poultry, etc.), or a type of livestock (cattle, hogs, sheep, etc.). It is synonymous with the term "farm activity". Diversification and specialization are antonyms.

The existing studies have investigated it in a static, cross-sectional form, or at best over a small increment of time. Heady (1952), Stovall (1966), Johnson (1967), Hackbart and Anderson (1975), Pope and Prescott (1980), Brown (1989), and Kerr (1989) are a few examples. Some of these have expounded the microeconomic theory of diversification in a farm management setting (Stovall, 1966; Johnson, 1967), while others have simulated enterprise portfolios and examined correlations, income variance, and other characteristics in light of microeconomic theory (Heady, 1952; Brown, 1989; Kerr, 1989). However, these studies could be read as farm management or microeconomic textbook material. Furthermore, drawing conclusions from cross-sectional studies of diversification can be dubious if not carefully evaluated (Mishra *et al*, 1999).

There is a gap in the literature. First, a robust measure of long-term change in farm diversification is lacking. Second, an attempt has not been made to explain the specific forces driving changes in diversification. This thesis is intended to begin filling that gap. It thus serves a dual purpose. One function is to empirically document the evolution in Iowa farm diversification during the 20th century. The other function is to propose an economic hypothesis that sheds light on the evolution.

The hypothesis will have a fairly narrow focus. A system as complex as American agriculture, when subjected to such a thorough, holistic change, is bound to be tied up with several variables. One characteristic of the system, such as diversification, will interact with those several variables. It will also be related to the other characteristics of the system, such as farm size, labor, and others previously listed. This makes for an intricate web. A complete explanation is difficult, to say the least. An attempt was made to identify a common thread running through all parts of the system. What variable has a part to play in changing all aspects of the system? Technology is certainly a candidate. It is closely related to farm size, labor, structure, and so on (Gardner, 2002, p. 8). Here it is hypothesized that technology, along with agronomics and transactions costs, is the primary cause of the trend observed in Iowa farm diversification during the 20th century.

The remainder of the thesis is organized as follows. Chapter two will discuss the theory behind the hypothesis. Chapter three presents an empirical measurement of Iowa farm diversification. It fulfills the purpose of documenting the change. The documentation will also help flesh out the other part of the dual purpose, the explanation. Along with the case studies of chapter four, it will dovetail with the theory of chapter two and set forth a complete picture of the hypothesis. The fifth chapter details an econometric test of the hypothesis. A discussion of the test methodology and the results is included. Finally, chapter six concludes the thesis with a brief summary of the content, ideas about the future of farm diversification, and suggestions for future research.

CHAPTER 2. THEORETICAL CONSIDERATIONS

The objective of this chapter is to explore the theory behind farm enterprise diversification. Specifically, it discusses theory that can aid in explaining how the enterprise mix has changed in the 20th Century. Two different frameworks are examined. First, portfolio theory and its applicability to farm diversification are examined. Second, a micro level approach is presented in the form of farm firm theory.

Portfolio Theory

A natural topic to begin an examination of farm diversification is portfolio, or diversification, theory. It rears from the world of finance and investment theory. The intent of this section is not to rehash investment theory, covered thoroughly elsewhere. Rather, a brief review is given, followed by a critical assessment of the theory's application to farm enterprise diversification.

The seminal work on portfolio selection was done by Markowitz (1952, 1959). An efficient portfolio of investments is determined by two moments, the mean and variance of its return. If a level of expected income is given, the portfolio yielding the lowest income variance is said to be efficient. Equivalently, a portfolio yielding the highest level of expected income for a given amount of variance is also efficient. A collection of the points at which efficient portfolios lie forms a curve called the Markowitz efficiency frontier. This frontier forms the upper bound on the feasible set of portfolios. The feasible set is restricted by two conditions. First, it is bounded above, which is fulfilled if the returns on the different enterprises have finite means and variances (Johnson, 1967). Second, the upper bound is strictly concave, which is fulfilled if the covariance matrix of returns for the enterprises is positive definite (Johnson, 1967). The efficient portfolio chosen from those on the frontier will depend on the investor's risk preferences (Stovall, 1966).

A risk-averter will always want to diversify. Consider two assets, x and y. They will be combined in portfolio R, x with share a and y with share $(1 - a)$, $0 \leq a \leq 1$. The variance of portfolio R is:

$$(1) \qquad \sigma^2_R = a^2\sigma^2_x + (1-a)^2\sigma^2_y + 2(a)(1\text{-}a)\sigma_x\sigma_y\rho_{x,y}.$$

Minimizing (1), the variance function, with respect to a:

$$d\sigma_R/da = 2a\sigma^2_x + (2a\text{-}\ 2)\sigma^2_y + (2-4a)\sigma_x\sigma_y\rho_{x,y} = 0$$

$$\rightarrow \qquad = a(2\sigma^2_x - 4\ \sigma_x\sigma_y\rho_{x,y} + 2\ \sigma^2_y) = 2\sigma^2_y - 2\ \sigma_x\sigma_y\rho_{x,y}$$

$$(2) \quad \rightarrow \quad a^* = 2\sigma^2_y - 2\ \sigma_x\sigma_y\rho_{x,y}/(2\sigma^2_x - 4\ \sigma_x\sigma_y\rho_{x,y} + 2\ \sigma^2_y)$$

To simplify, let $\sigma^2_x = \sigma^2_y = \sigma^2$. Now, equation (2) becomes:

$$(3) \qquad a^* = (1\text{-}\ \rho_{x,y})/2(1 - \rho_{x,y}) = 1/2.$$

The optimum portfolio contains x and y in equal proportions. This is a theorem first proved by Samuelson (1967). Two investments with independent and identical distributions of returns will give optimal diversification with the investments in equal proportions in the portfolio (Samuelson, 1967). This holds for a risk-averter with a strictly concave utility function and equal means in the returns. This has been extended to *n* interdependent (correlated) investments, and to cases in which the returns are not identically distributed (Samuelson, 1967; Hadar and Russell, 1974). If there are *n* assets, the optimum portfolio has each asset with proportion $1/n$.

In a more general case, Brown (1989) mentions that the variance of a portfolio of assets will always be less than or equal to that of an individual asset. To see this, return to equation (1). Again, assume $\sigma^2_x = \sigma^2_y = \sigma^2$. Set $a = 1$. Then portfolio variance, σ_R, is σ^2. The same result is obtained if $a = 0$. Now, set $a = 1/2$. The result is:

$$(4) \qquad \sigma^2/4 + \sigma^2\rho_{x,y}/2 + \sigma^2/4 = \sigma^2/2(1 + \rho_{x,y}).$$

The variance depends on the correlation coefficient. Since the upper bound on $\rho_{x,y}$ is 1, the maximum of equation (4) is σ^2. Any correlation value of $-1 \leq \rho_{x,y} < 1$ will result in a fraction of σ^2. This holds for any value of a. Again, a is bounded by 0 and 1. If the variances σ^2_x and σ^2_y are not equal, there will still be a value of a that makes the portfolio variance less than that of either asset. Lower correlation values between asset returns will make diversification more attractive, but even high, positive values of rho will yield gains from diversifying. Brown (1989) showed that adding assets to a portfolio substantially decreases its variance with the asset returns correlated at .5.

The ideas presented above do not mean an investor will always invest in as many assets as possible. The main idea is that diversification always helps because it increases the choice set. There will be more options from which an investor can choose. There are other considerations that determine the best option, or the optimal portfolio of assets.

The Capital Asset Pricing Model

An alternative method of measuring an investment's risk is provided through the familiar Capital Asset Pricing Model (CAPM). It was derived by Sharpe (1964) and Treynor (1961). It has since been extended by Lintner (1965a, 1965b), Mossin (1966), and Berk (1997), among others. CAPM assumes that a correctly valued investment should yield the risk-free rate (government treasury securities) plus a premium to compensate for risk, which is measured by its beta value. Beta is defined as the investment's correlation coefficient with a market portfolio, multiplied by its own standard deviation, and then divided by the market's standard deviation (Sharpe, 1964). The market's beta is 1.0. An investment with a beta of 1.0 has an expected return equal to the market's expected return. A high beta indicates high systematic risk, and vice versa. The relationship between beta (its systematic risk) and expected return forms the security market line, which is linear and shows the risk-return trade-off for the market (Sharpe, 1964).

CAPM extends portfolio theory in three important aspects. First, only the nonsystematic risk component of a portfolio can be eliminated. To see this, consider the beta value as the slope of a regression line. The variation in an investment that changes with the market portfolio variation is the systematic component. The residual of the regression, or the standard error, is that component uncorrelated with the market portfolio. This is the unsystematic component. If follows that the portion of an asset's risk which stems from its correlation with the return on the market cannot be eliminated by adding that asset to the portfolio. In other words, no matter how well-diversified a portfolio consisting of assets from the market, the portfolio's systematic risk cannot be eliminated. Common sense dictates that a strong correlation between an asset and the market will necessitate a high expected rate of return for that asset to compensate for the high systematic risk.

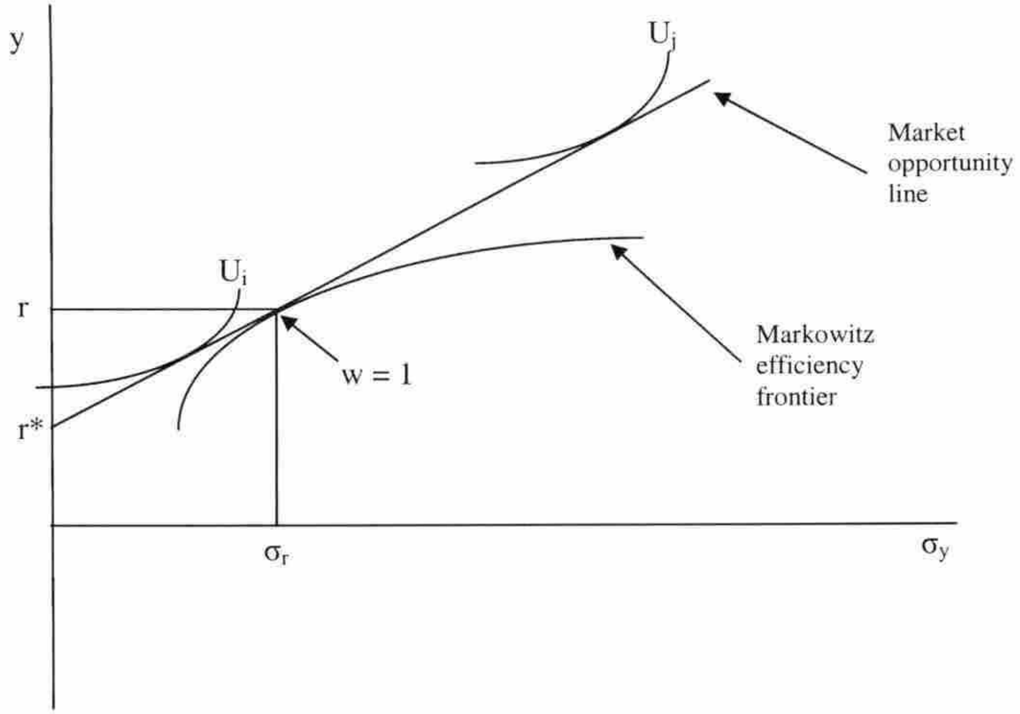

FIGURE 2.1 Portfolio selection (from Lintner 1965b)

The second extension, as given in Lintner (1965b) shows that there is one optimal mean-variance combination, but many different portfolios possess that combination. This is shown in Figure 2.1. Define y as the return on the market and σ_y as the standard deviation of the market return. Define r as the return on a given portfolio of assets, σ_r as the standard deviation of that portfolio, r* as the risk-free rate, and w as the ratio of investment in risky assets to total net investment. The investor chooses a portfolio along the market opportunity line with the maximum slope. That is, the investor maximizes θ, the slope of the line, defined as

$$\theta = (r - r^*)/\ \sigma_r.$$

Naturally, this is the slope that is tangent to the market opportunity line, as it gives the set of efficient portfolios. Any portfolio along this line is efficient because it is a linear combination of the optimal mean-variance combination. In other words, for any expected return the investor chooses, it will have the minimum variance. A more risk-averse investor will perhaps choose the portfolio represented by indifference curve U_i ($w < 1$, a saver). One who is less risk-averse could be represented by U_j, with a higher expected return and higher variance ($w > 1$, a borrower).

Two important corollaries follow from Figure 2.1. One is the separation theorem of Tobin (1958). As given in Lintner (1965b), return on total net investment is:

$$(1) \qquad y = (1 - w)r^* + wr = r^* + w(r - r^*);\ 0 \leq w < \infty$$

The mean and variance of net investment are:

$$(2a) \qquad y = r^* + w(r - r^*)$$

$$(2b) \qquad \sigma^2_y = w^2\, \sigma^2_r$$

Equating 2a and 2b to eliminate w yields:

$$(3a) \qquad y = r^* + \theta\, \sigma_y, \text{ where}$$

$$(3b) \qquad \theta = (r - r^*)/\sigma_r.$$

As demonstrated above, θ is first maximized. Substituting this value into (3a) and choosing the (y, σ_y) pair that fits with the investor's utility function will yield a y value. This, in turn, can be plugged into (2a) to determine w (since r and r* are known). The investor's choice of the optimal portfolio is independent of how intensively the portfolio is utilized, or the value of w.

The second corollary from Figure 2.1, stressed by Lintner (1965a), shows that diversification is meant to provide the best available combination of risk and return. The object of diversifying is not to minimize risk *per se*. Any risk-averse investor wants to minimize risk for any given rate of return. The object is to find the portfolio with the best ratio of expected return to standard deviation of portfolio return, or the maximum θ. In practice, this portfolio is never the one with minimum risk. The optimal portfolio's extra return more than compensates for the added risk in holding it. An important consideration in diversification is the expected return that is given up to ensure less risk.

A third extension of portfolio theory by the CAPM expands the restrictions on utility functions. It was previously thought that one of two assumptions must hold true for the mean-variance approach to be technically correct. One assumption is normal distribution of returns; the other assumption states that the utility function depends only on mean and standard deviation. Samuelson showed that a two-moment utility function can produce a portfolio that does not necessarily fall on the efficiency frontier. The solution to the diversification problem is thus “optimal”, but not efficient (a misspecification problem). (Samuelson expressed dissatisfaction with the two-moment analysis of a statistical distribution, and argued for an analysis without means, variances, and covariances.) The CAPM was originally derived under this two-moment assumption, but recent work by Berk (1997) has shown that CAPM can hold if utility functions are polynomials of order N, $0 < N < \infty$. It can also hold if utility functions are not polynomial, but rather analytic functions. In this case, returns need not be normally distributed, but are elliptically distributed instead.

Applications to Farm Enterprise Selection

When one moves from pure diversification theory to agricultural economics, the means and variances of returns on investments is translated into mean income and variability of farm enterprise mixes. Heady (1952) was the first to thoroughly examine diversification and its application to income variability and planning under uncertainty, topics that had previously been given only passing mention in farm management and economics literature. Heady pointed out that diversification can serve the dual function of reducing year-to-year income fluctuations and reducing the probability of severe loss (bankruptcy) in any given year. He also explored how variance differed when resources, or enterprises, are added to an operation versus when resources are held constant but shifted among different enterprises.

Heady (1952) plugged variances of gross incomes of different crops into a simple two-enterprise model to compute minimum variance combinations, their corresponding income levels, correlation coefficients between pairs, and minimum and average incomes of various pairs. The data covered 1910 to 1950. The model used wheat, milo, and barley data from Fort Hayes, Kansas and corn, oats, hay, and wheat data from Monona County, Iowa.

Since Heady’s study, several empirical and theoretical applications of diversification and portfolio theory have been made to farm enterprise diversification. Empirical studies of farm enterprise diversification are myriad. Pope and Prescott (1980) conducted a cross-sectional analysis of diversification's relationship to socioeconomic characteristics on California crop farms. White and Irwin (1972) used Census of Agriculture data in a discussion of the relation between size and diversification. Kerr (1989) investigated the correlations and covariances among 27 commodities for the period 1977 to 1986 in a study of potential effects of diversification in Canadian prairie agriculture. Brown (1989) and Turvey and Driver (1987) used the CAPM approach in studies of the mean-variance trade-offs of different enterprise mixes, also in Canadian agriculture. Stovall lists studies of diversification and income variation for crop mixes in California, Oklahoma, Kentucky, and Illinois. These are similar to Heady's analysis of Iowa and Kansas crop mixes. Gardner (2002, pp. 136-140) calculated a correlation matrix for fifteen agricultural commodities using U.S. price data covering the period 1911 to 1996.

In the realm of theory, Stovall (1966) discussed farm planning that extended Heady's two-enterprise model. It included land and income constraints, with a quadratic programming technique suggested as a means of finding the feasible, maximum-income allocation of two enterprises. Johnson (1967) applied Tobin's separation theorem to argue that the optimal portfolio of risky farm enterprises is unrelated to the portion of land devoted to risky enterprises out of total land owned (the ratio of risky to riskless enterprises).

What, then, does portfolio theory reveal about selection of farm enterprises? Common sense says that if diversifying through adding enterprises always helps reduce variance and increases the opportunity set, a farmer should be diversified into as many enterprises as possible. This is especially so if enterprise returns are iid with equal means. Such a high degree of diversification is not observed in reality. The CAPM gives some hints on the reasons behind this.

First, the CAPM illuminates the important fact that only nonsystematic risk can be diversified out of a portfolio. If the systematic risk, or that of the market portfolio, is very high, it does not bode well for the risk-averse investor since the systematic risk cannot be eliminated by investing within the market. Gardner concluded that even the most diversified commodity portfolios are quite unstable. The studies of Canadian agriculture have also concluded that diversification within agricultural enterprises is limited (Brown, 1989; Turvey and Driver, 1987; Kerr, 1989). It should be pointed out that small positive correlations can substantially reduce portfolio variance, but most commodities do not even exhibit this property (Brown, 1989; Gardner, 2002, pp. 139). These studies suggest that even if nonsystematic risk in agriculture can be diversified away, the high systematic risk inherent in the agricultural sector makes farm enterprise diversification ineffective in dealing with risk.

Second, the optimum mean-variance combination of a portfolio of farm enterprises (the highest θ) is not the one with the lowest variance. The best risk-return trade-off will be chosen by the farmer. This is especially vital in an agricultural setting, where economies of size cause disparities in mean returns and government price support programs affect risk of returns. These issues are thoroughly discussed in the next section.

Third, the separation theorem gives some insight into the size of a farm operation. Once the optimal enterprise mix is chosen, the farmer must choose how intensively to utilize that mix. This is the same as choosing a portfolio along the optimal market opportunity line. Again, this idea is augmented by the discussion in the next section.

Finally, skewed income distributions often appear in agricultural settings and utility functions with higher moments are commonly found in agriculture (Brown, 1989). This could warp an examination of farm enterprise selection based on the assumptions of normality of returns and two-moment utility functions. However, Berk's work shows that CAPM can possibly be utilized with non-normal distributions and high moment or analytic utility functions.

One can see that CAPM provides a framework within which to analyze farm enterprise selection. However, it has limitations. Other factors will determine the optimal product mix and the intensity of its use. A key limitation underlying mean-variance analysis is the assumption of zero transactions costs. This is an especially important assumption of CAPM (Lintner, 1965). An investor can allocate a stock of a perfectly divisible capital among investments with little to nil transaction and coordination costs. In CAPM, this means dividing money among securities. However, in agriculture, capital (which is far from being perfectly divisible) is allocated among farm enterprises that might require significant costs in the form of management, supervision, and coordination. In terms of planning and management requirements, starting a hog farrow-to-finish operation is significantly different from adding another stock to a portfolio.

Two major ideas emerge from portfolio theory: 1) reducing variability of income through diversifying into different farm enterprises seems difficult, and 2) CAPM is a good framework but has limitations. The questions thus remain: What is the purpose of a farm enterprise combination? What causes that combination to change over time? Does the farmer even view risk as a factor when deciding an enterprise mix? Answers can possibly be found in the theory of the farm.

The Theory of the Farm

A longstanding issue that has vexed economists is the continuing existence of the family farm. As Allen and Lueck (2000, p. 643) comment, "The average economist has shown a remarkable fascination with farming and its various economic details even though the average economist knows almost nothing about farming." To the average economist, it seems family farms, particularly of small and medium size, are anomalous. The rapid technological advances of recent decades should have "industrialized" all aspects of agriculture, making the traditional family farm suboptimal, thus spelling its doom. This issue does not directly bear on farm diversification, but there are some indirect linkages that make the theory of the farm pertinent to diversification[1]. An explanation for the persistence of family farms provides insight into the patterns of diversification observed on those farms.

First, the theory of the profit-maximizing firm does not accurately describe the family farm. Rather, the theory of farm households is appropriate (Schmitt, 1991). Optimal farm size must be analyzed within a framework that accounts for on-farm and off-farm use of the resources available to the household. Put another way, the firm is a goods and services firm, providing not only agricultural goods, but also services such as custom farm work and labor for off-farm jobs (Madden and Partenheimer, 1972).

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[1] For a thorough discussion of farm structure see Allen and Lueck (1998) and Schmitt (1991, 1992). Full reference information is given in the "References" section at the end of the paper.

Second, transactions costs are cited as a major advantage for the family farm in organizing agricultural production. This closely follows the famous Coase theory (Coase, 1937). The organizational form with the highest revenue net of transactions costs will win out in the end. These costs arise out of market imperfections and uncertainties resulting from imperfect information (Schmitt, 1992). Madden and Partenheimer (1972) identify six types of uncertainty facing farms: price, yield, cost, technological, human, and institutional. In general, transactions cost is a catch-all term for any cost founded to reduce those uncertainties (Schmitt, 1992). Specifically, they are costs of arranging, monitoring, and enforcing contracts (Schmitt, 1992). They need not involve a market exchange, but always concern the maintenance of property rights (Allen and Lueck, 2000).

Schmitt (1990) views lower transactions costs of farming organized by farm families versus large farms using hired labor as the prime reason for the superiority of family farms. Indeed, hired labor gives rise to human uncertainty and the principal-agent problem, which in turn creates moral hazard. Transactions costs result from monitoring and supervising efforts that mitigate moral hazard.

Three characteristics of agriculture make monitoring costs high. One characteristic is its spatial nature. This is emphasized by Schmitt (1991) and Pollack (1985). Production is decentralized, sometimes covering thousands of acres for crop farms and tens of thousands for ranches. Monitoring such a dispersed labor force is expensive. Economies of size might point the way to such large sizes (as will be discussed later), but the transactions costs will outweigh any productivity gains of size economies.

A second characteristic that can cause high transactions costs is complexity of assets (Allen and Lueck, 2000). Madden and Partenheimer (1972) give examples such as fields composed of different soil types, a diverse dairy herd, and a diverse beef feedlot. The farmer will often find it easier to do the work instead of micromanaging hired labor that is sure to be less familiar with the proper ways of farming with such nonuniform resources.

The third, and perhaps most important, characteristic is seasonality, or uncertainty introduced by nature. Allen and Lueck's (1998) major contribution to understanding farm ownership structure came in their paper *The Theory of the Farm*. Clearly a take on Coase's *The Nature of the Firm*, they melded Coase's theory with seasonality to explain farm organization under a variety of conditions. They argue that seasonality, or the periodic nature of biological processes inherent in crop and livestock production, is the major force that separates farm organization from industrial organization. It makes intuitive sense that it is a primary force preventing the industrialization of all agriculture.

Many economists ponder why multi-thousand acre, highly specialized farms have not replaced all small, family-oriented farms. Allen and Lueck (1998) go further and ask why each stage of production is not specialized into separate firms. In this context, specialization means one firm does the planting, another the chemical application, another the harvesting, and so on. However, gains from specialization in agriculture are minimized by seasonal factors. Essentially, "Production stages in farming tend to be short, infrequent, and require few distinct tasks, thus limiting the benefits of specialization and making wage labor especially costly to monitor" (Allen and Lueck, 1998, pp. 346-47).

Seasonality further complicates agricultural production because each stage must be completed in a timely fashion. Substantial yield loss can occur if either the crop is not planted and harvested at optimum times, or if weeds and pests are not controlled appropriately. Again, a farmer has motivation to perform each task. As Allen and Lueck (1998, p. 355) state, "With production uncertainty (at each step), hired workers have incentives to shirk because, unlike family farmers or partners, they are not residual claimants."

In summary, two main ideas emerge from the theory of the firm: 1) spatial, seasonal, and asset complexity factors cause substantial transactions costs in the form of coordinating time-sensitive stages and monitoring hired labor, and 2) farms organized by families offer not only farm products, but also services such as custom farming and labor for off-farm jobs. Both point to the family farm as the superior form of agricultural organization. Also, these ideas, combined with technological considerations, can explain diversification at the farm level.

The Technology Theory of the Farm

Sometimes, technology changes a production process, which changes the on-farm product mix. For example, horses and mules were the main source of power for field crop operations during the first part of the 20th Century. Oats were grown as "fuel" for the horses. As mechanical power replaced horses, oats were no longer necessary. A field crop and a type of livestock were eliminated, which decreased diversification. Furthermore, rotations of row crops, small grains, and forage served several functions. Those included erosion prevention, fertility conservation, forages grown for livestock, spreading labor requirements, and control of weeds, diseases, and pests. Technology has allowed purchased inputs to perform these functions. Erosion is controlled through terracing, no-till, and strip-till methods. Chemical inputs control weeds. Biotechnology makes row crops resistant to many disease and insect infestations. Nitrogen fertilizer is used instead of manure. Nearly every production problem in agriculture can be solved or at least alleviated with purchased inputs. This has caused many farms with multi-crop rotations and livestock to specialize into solely row crop operations (White and Irwin, 1972).

At other times, technology overcomes spatial or seasonal constraints. As Allen and Lueck (1998, p. 347) point out, "When farmers are successful in mitigating the effects of seasonality and random shocks to output, farm organizations gravitate toward factory processes, developing the large-scale corporate forms found elsewhere in the economy." This is where transactions costs enter the picture. When spatial and/or seasonal constraints are overcome, the benefits that accrue from expanding into factory-style production outweigh transactions costs.

Industrialization of agriculture is nowhere more evident than in livestock production. Stock can be grown in climate-controlled buildings where technologies in disease control, handling, nutrition, and transportation can temper or even eliminate seasonal factors (Allen and Lueck, 1998). Also, labor is highly specialized, centrally located, and involves routine jobs (Madden, 1967). This drastically cuts supervision and monitoring costs. Innovations in information technology and genetics have also had a big impact. The food system, based on the demands of the American public, has increasingly developed into one providing convenience, consistency, and variety in products (Hennessy *et al*, 2003). A highly controlled environment and the ability to store and manage large amounts of data are necessary to meet the demands of the system (Hennessy *et al*, 2003). The environment allows for control of genetics and experiments that consistently produce homogeneous lots of product for processors. The information technology allows information about the nature of the inputs to be properly managed and disseminated to processors and to the public. Industrialized operations are in a better position to meet these demands.

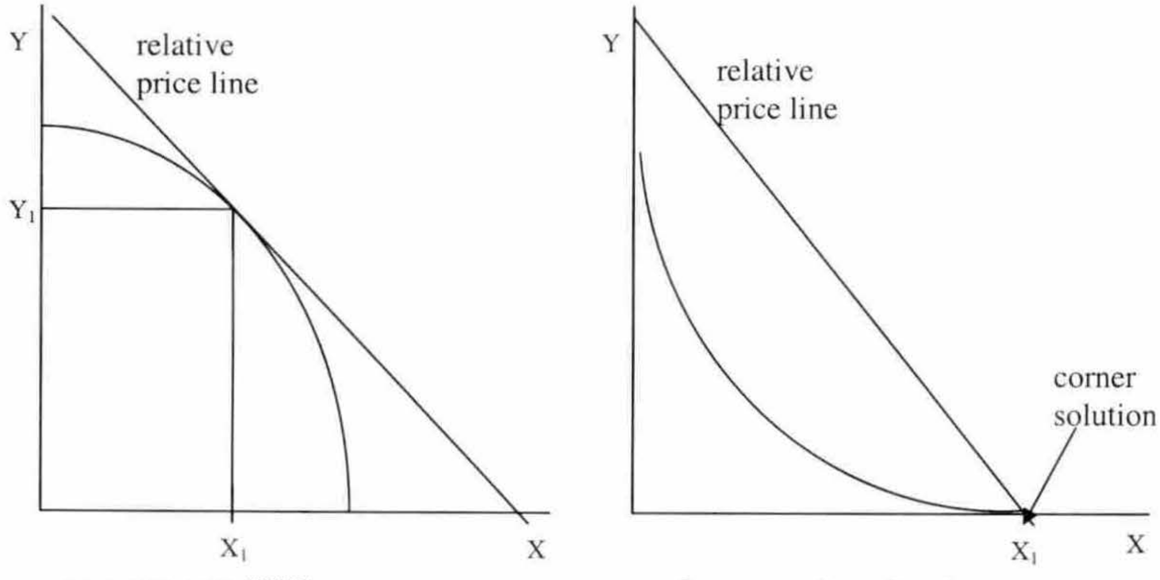
Cattle feeding is a good example of an industry that was composed of farmer-feeders in the first half of the 20th Century but has evolved into one composed almost exclusively of corporate firms over the last four decades (Allen and Lueck, 1998). Labor is specialized into accountants, feed purchasers, cattle purchasers, veterinarians, engineers, and unskilled workers who perform routine operations (Allen and Lueck, 1998). Contractual arrangements are made with a few select suppliers of feeder cattle and a few buyers of fattened cattle, sometimes as few as one supplier and one buyer (Sundquist, 1972). Fattened cattle can be sold on a weekly or even daily basis (Allen and Lueck, 1998). These "cattle hotels" can thus maintain a uniform cash flow (Krause and Kyle, 1970). Uncertainties related to spatial, production, and seasonal concerns are largely eliminated. The family farmer will not find it necessary to compete on a smaller scale (Krause and Kyle, 1970).

A similar story is found in the broiler and hog industries. The broiler transformation began in the 1930's, before cattle feeding reorganized, while the hog industry changeover has been more recent, mostly during the last two decades. A highly controlled environment for product experimentation has been especially important for these two industries (Hennessy *et al*, 2003). The take-home message is that technological change during the past century has taken three types of livestock production from the domain of the family farmer and placed them squarely in the realm of industrialized, factory production. Obviously, this has reduced diversification at the farm-level as those enterprises become uncompetitive and are eliminated by the farmer.

It is much more difficult to conquer seasonality with technology for crop agriculture. Even so, transactions costs still have a role to play in explaining the mix of enterprises that are not taken away by industrialization. Again, the discussion starts with the impact of technology.

American agriculture has become more capital-intensive as labor-saving technology and purchased inputs have become the norm in production. The nature of the technologies has created economies of size, as it is necessary to spread high fixed costs over more units of production. This means more units of production are gained from the same amount of inputs.

Economies of size will tend to drive specialization. The optimal product mix is set by the technical production functions for the different enterprises and relative product prices (White and Irwin, 1972). The shape of the technical production function, termed the transformation surface, or production possibility frontier (PPF), will determine the marginal rate of substitution (MRS) between pairs of products. When products compete for a fixed



a. a concave PPF causes optimality of diversification among products X_1 and Y_1

b. economies of scale cause a convex PPF and product specialization in X_1

FIGURE 2.2 Substition relationships

bundle of inputs, economies of size will cause the concave transformation surface to become linear or convex (Pope and Prescott, 1980). The rule for profit maximization equates the slope of the transformation surface with the negative price ratio. Figure 2.2a shows how diversification is optimal when marginal product-product substitution is increasing. Figure 2.2b demonstrates the result when economies of size cause a decreasing marginal rate of substitution. It will entail a corner solution, or product specialization.

Of course, a farmer does not have to specialize. The technology could enable the easy production of a small output of several row crops, while still leaving considerable time for livestock, small grains, and forage enterprises. However, to take advantage of the technologies and avoid inefficiencies, a farmer must operate each enterprise at a certain size (Shucksmith *et al*, 1989; Brown, 1989). Brown calls this the threshold size. It is the size at which the long run average cost (LRAC) curve starts to flatten. Enterprises smaller than this are likely to experience diseconomies and negative economic profits. Assuming that a farm faces capital and land constraints, growing the size of select enterprises will occur at the expense of other enterprises.

It is possible that a farmer could change the proportion of enterprises instead of completely specializing. Again, the characteristics of technological development and changes in markets will more likely cause enterprises to be dropped. The transformation surface is generally assumed to be continuous, which means a large number of fixed inputs are varied in tiny increments, thereby enabling enterprises to be mixed in almost any proportion (White and Irwin, 1972). More factor markets enable inputs and technologies to be hired, rented, or leased in any amount. They become variable. Reducing the number of fixed inputs to only a few will introduce discontinuities into the surface and make it linear. This makes the corner solution, and specialization, more likely (White and Irwin, 1972).

Capital inputs possess two more characteristics that change the product-product substitution relationships. First, they often favor one type of enterprise (White and Irwin, 1972). Second, they are discrete, or "lumpy" (White and Irwin, 1972; Madden and

Partenheimer, 1972). A farmer must choose how to allocate limited capital among lumpy, enterprise-specific inputs. This would seem to lead to specialization.

Farm Size

As economies of size change the shape of the transformation surface, the threshold size of an enterprise and the nature of capital inputs dictate that farms will become more specialized. This assumes enterprise size grows as farm size remains constant, but there is strong incentive to expand the farm. Surveys of studies indicate moderate sized farms are able to capture most economies of size (Brown, 1989; Raup, 1969; Butcher and Whittlesey, 1966; Schmitt, 1991; Madden, 1967). However, capital-intensive technologies push the LRAC curve down and to the right as they are introduced. Farms must grow at least enough to keep within the range of efficient production (Butcher and Whittlesey, 1966; Nikolitch, 1969). Also, labor-saving technology frees up labor resources of the family-operated farm. It must be expanded to fully take advantage of the technology and avoid wasting labor (Butcher and Whittlesey, 1966).

The following analysis from Herdt and Cochrane (1966) demonstrates how biased technological advance prompts farm expansion. In equilibrium, the marginal physical product (MPP) and price (P) of land (L), labor (N), and capital (K) are related to the marginal cost (MC) and price (P) of product Y in the following equality:

$$\frac{MPP_L}{P_L} = \frac{MPP_N}{P_N} = \frac{MPP_K}{P_K} = \frac{1}{MC_Y} = \frac{1}{P_Y}.$$

Labor-saving technological change will cause the MPP of labor to decrease against the MPP of land and capital, yielding:

$$\frac{MPP_L}{P_L} = \frac{MPP_N}{P_N} > \frac{MPP_K}{P_K} < \frac{1}{MC_Y} = \frac{1}{P_Y}.$$

The disequilibrium will prompt the use of more capital and less labor, resulting in:

$$\frac{MPP_L}{P_L} > \frac{MPP_N}{P_N} = \frac{MPP_K}{P_K} = \frac{1}{MC_Y} = \frac{1}{P_Y}.$$

The farmer now has motivation to buy land until the MPP of labor decreases and/or price of land increases to restore equilibrium.

As farm size is increased, either current enterprises will increase in size, or more enterprises will be added. It is more likely that expanding farmers will opt for the former. The same surveys of the economies of size studies mentioned above also indicate that the LRAC curves are L-shaped and remain relatively flat over a wide range of output (often to the extent of the data) (Brown, 1989; Raup, 1969; Butcher and Whittlesey, 1966; Schmitt, 1991; Madden, 1967). Hence, increasing the size of an enterprise increases profits because gross revenue increases while average costs remain flat. A farmer expanding the size of his operation will devote added resources to the specialized enterprises to maximize returns. Pope and Prescott (1980) identify the key question pertaining to specialization versus diversification as: What is the trade-off between increased returns from exploited economies of size versus income stability from a diversified product mix? Unless enterprises yield exactly the same return and are perfectly, positively correlated, some measure of return is always given up if diversification is chosen (Heady, 1952). It appears that significant returns are forgone if economies of size are not captured. It is especially costly if diversification is unsuccessful at reducing income variance. As the explained in the "Applications to Farm Enterprise Selection" section, this is often the case in agriculture. This lends further credence to specialization as the optimal choice as the farm is expanded.

The maximum slope (max θ) of the market opportunity line in an agricultural setting appears to involve a specialized portfolio. The extra gains in return from economies of size more than compensate for the added risk of specializing. In fact, it will be argued shortly that much of the risk has been removed from specialized production.

Returning to the separation theorem, the farmer must decide on the portion of land to put into the specialized product mix. In a farm setting, the risk-free borrowing and lending rate, r^*, is equivalent to renting and leasing out land (Johnson, 1967). A farmer can either "lend" by leasing out land to others, or "borrow" by renting land from others. It is rare for a farmer to utilize part of owned land and lease out the remainder (the lending case). A farmer either uses all owned land, or uses all owned land in addition to renting from others. In the context of Figure 2.1, farmers are more likely to be represented by indifference curve U_j.

Again, economies of size encourage expansion of the farm. One way of doing this is by renting land. In Iowa, about 50 percent of all land farmed is now rented land.

If a farmer can increase profits by expanding an enterprise, why not expand several enterprises to the outer reaches of the LRAC curve? The simple answer is that not all enterprises are equally profitable. Samuelson's theorem stating the optimality of investing equally in all enterprises does not apply because economies of size introduce significant disparities in mean return, which violates the equal means requirement of the theorem. Also, capital is likely to be added in smaller increments, not large infusions. Lumpy, enterprise specific capital will be applied to the specialized enterprises that are already above the threshold size instead of attempting to build up new enterprises. A more complete answer will bring transactions costs into the picture.

Transactions Costs

Diversifying into new and various enterprises involves added risks and investments (Gertler, 1996). More uncertainty is introduced because each enterprise comes with its own price, yield, cost, and technological uncertainties. This requires coordination. Madden and Partenheimer (1972) state that coordination is a dynamic function that is necessary under conditions of uncertainty and disequilibrium. The Marshallian static equilibrium under perfect competition does not really happen because of market imperfections and uncertainties. Recall that transactions costs economics originated as an attempt to deal with those uncertainties. Coordination of multiple enterprises represents transactions costs. The full cost of diversification is not usually acknowledged in the portfolio approach (Heady, 1952).

Coordination becomes more difficult as the farm becomes more diversified (White and Irwin, 1972). Madden and Partenheimer (1972 , p. 103) state, "As the farming operation becomes large and more complex, the number of unpredictable situations requiring attention becomes burdensome because the coordinator must relate each decision to all the other decisions that have been made or are going to be made." Production processes often overlap, and are further complicated by the spatial and seasonal factors so prevalent in agriculture.

Custom hiring can enable coordination among sequential stages of different enterprises and thus gain output from them. This is fraught with uncertainty because the biological processes are so sensitive to timing. A custom operator who fails to perform a task at the right time subjects the owner to severe losses. The moral hazard problem crops up again. Also, the optimal time might require an on-the-spot decision being made (take harvesting a certain field, for example). Obtaining custom work on such short notice is uncertain. The farmer will find it easier to take on only the number of enterprises that can either be properly managed with his own land, labor, and capital, or that involve tasks for which custom hiring is not risky. Specialization enables a farmer to focus capital and coordination efforts on fewer commodities, but on a larger scale (Gertler, 1996).

Transactions costs can be significant if new enterprises need to penetrate markets or create new opportunities (niche markets) (Gertler, 1996). This can mean there are significant "search costs" that accrue as a new product is marketed. A producer that attempts to enter a filled niche market can potentially incur large losses (Gertler, 1996). Also, a niche market that fails to develop as planned can suffer the same fate. These considerations will certainly cause a producer to be wary of diversification.

Two other factors pertaining to search costs have provided incentive to specialize. One is a well-developed infrastructure that has reduced transportation costs and integrated markets. The highway system, river barges and lochs, railroads, county elevators, and the overall grain origination and handling system make it a simple, low-cost task to get one's product to market. This encourages the farmers of a region to "do what they do best".

The second factor is futures and options exchanges, which have developed for the major agricultural commodities produced in a certain region. They provide efficient price discovery and transparent markets. A producer with crops that are traded on the exchanges knows precisely what his output is worth in the present as well as several months forward. Futures, options, and forwards offer ample opportunity for risk management. There is incentive to produce those commodities traded on the derivative markets.

One can see how search costs were low in the past, even with highly diversified family operations. Row crops, forages, and small grains were grown according to rotational needs, with livestock operations providing a market for the field crops. Livestock was used for family consumption or sold at local terminals. Everything had a ready market. As production agriculture has become completely commercialized, the infrastructure and institutions have evolved to maintain low search costs, facilitating a specialized product mix in a region.

Government Policy

Government agricultural policy has its origins in commodity price-support legislation enacted during the farm crisis of the Great Depression (Orden *et al,* 1999). Since then, various policy instruments have been enacted, including income safety nets, land set-asides, the Commodity Credit Corporation (CCC), the conservation reserve program (CRP), direct subsidies, and government storage. Empirical studies of government policy and diversification are few in number. Just and Schmitz (1989) simulated the effects of policy on crop mixes in Canada. They found the results to be ambiguous, depending on the policy instrument and current enterprise mix of a region. Smith and Young (2003) conducted a study comparing the impact of differing Canadian and American polices on cropping diversity along the U.S-Canada border. They suggest that set-aside programs have the greatest affect. Specifically, they increase diversification. Intuitively, this makes sense. If production of one major crop, say wheat, is reduced, at least one other crop will take its place. However, this is not necessarily so. If there are two major crops in a region, and one is entered into a set-aside program, the other one might simply fill the gap, leaving the same two crops. Again, the evidence of policy's impact on diversification is scant.

It is widely acknowledged that government farm subsidies are capitalized into land values. The subsidies raise farm income, but also increase cost of production through higher land prices. It might very well be that the total affect is a wash. There is impact neither on diversification, nor on other economic variables such as net income.

It is certain that price supports have reduced the "cost" of specialization. Heady (1952) argued that one function of diversifying the farm enterprises is to avoid the catastrophic year that will knock a producer out of business. Minimizing income variance in the short-term is necessary to long-run profit maximization since it keeps a producer "in the game". Government price supports, subsidies, and multi-billion dollar relief bills now serve to keep a farmer in the game by cutting off the lower tail of the probability distribution of returns (Gardner and Pope, 1978). In fact, technology, combined with subsidies, serves to encourage large output of specialized production because even large outward shifts in the supply curve from increased productivity do not result in lower prices (Gardner and Pope, 1978). One could argue that subsidized crop insurance serves the same purpose, although Gertler (1996) mentions that it likewise reduces the risks of diversifying into specialty crops. Presumably, the crop insurance for the major crops would guarantee at least some income if the specialty crops (for which insurance is not likely available) fail.

The lower end of the income probability distribution is cut off, but the upper tail is left wide open. Commodity prices are quite volatile, which means there is always the chance for a large income if prices jump into the upper tail. Over time, it is almost certain that the average income from highly variable year-to-year income of specialized production is higher than the average income produced by the more stable year-to-year income of diversified production (Schmitz, 1989). If a farmer does not view risk and income variance reduction as factors in enterprise selection, it makes more sense to specialize in order to capitalize on the "boom" years, especially if safety nets are in place to carry through the "bust" years. This improves the risk-return trade-off, giving yet another reason to suspect that the optimal market opportunity line entails a specialized portfolio.

Summary

Within a specialized farming context, the actual product mix will obviously be determined by agronomics. The foundation of farm planning has always been the crop rotations and the livestock operation(s) that dovetail with that plan (White and Irwin, 1972). Perhaps one of livestock's most important functions is to provide a market for the crops

(Zandtsra, 1992). Industrialization has taken livestock enterprises from the family farm. Technology has reduced crop rotations and driven specialization. Still, a region will specialize into what it produces best, which is ultimately an agronomic determination.

In summary, it seems that capital-intensive technologies have led to specialization of agriculture at the farm level in three ways:

1) they have transformed multi-crop rotations into one- or two-crop rotations as purchased inputs take over the roles formerly filled by rotations
2) they have overcome the seasonal and spatial constraints of livestock production, leading to their industrialization and making them inefficient and unnecessary at the traditional farm level
3) they have introduced economies of size into production, encouraging specialization, with the specialized product mix determined by agronomics and the minimization of coordination and search costs.

Frustration in attempting to identify farmers' risk preferences has been a barrier to research in enterprise diversification (Stovall, 1966). Notice that risk plays no part in this specification. It seems unlikely that a farmer views risk reduction as a factor in selecting an enterprise mix. Simply put, "Farmers do not make natural diversifiers…" (Shaw and Hale, 1996, p. 415).

The ideas presented above indicate that risk is handled not through enterprise diversification, but through alternative methods. Price risk is mitigated by government price supports and derivatives markets. Production risk is mitigated by biotechnology that creates drought-, pest-, and disease-resistant crops. New production technologies perform precise applications of fertilizers and herbicides through global positioning satellites (GPS) and variable rate (VR) technology. One could argue that much of the risk of specialized agricultural production has been removed. Several managerial tasks are moving away from the farm (Nikolitch, 1969). All the while, rents are captured by suppliers of the new technologies such as GPS, VR, genetically engineered seed, etc. Essentially, this means farmers face declining profit margins. One lesson from investment theory is that low risk investments carry a small reward, or low return, for bearing such a small risk. Returns to management in agriculture have become low.

Put another way, farmers are put on the "technological treadmill" (Evans and Ilbery, 1993). This discussion has emphasized several times that diversifying in order to reduce income variance means giving up substantial returns from lost economies of size. However, intense competition forces producers to buy increasing amounts of capital goods to keep pace with expanding technology that is necessary to lower production costs and maintain income (Evans and Ilbery, 1993; Nikolitch, 1969). The same competition makes it difficult to earn a profit from the technology, so ever-newer technological innovations are adopted in an attempt to further decrease costs (Clarke, 1994, p. 48). The treadmill is in full swing. Those that keep old technologies will eventually be unable to cover costs (Gardner, 2002, p. 267).

As this section explained earlier, new technologies spur specialization; but as just stated, they squeeze profit margins. This effectively raises the threshold size of an enterprise and gives the producer the incentive to expand into the outer regions of the LRAC curve because this will maintain income. What about those producers who are unable to expand their operations to sufficient size? The most probable answer says they seek income from non-farm sources. This is the second main idea from the theory of the farm. Instead of diversifying or trying alternative farming methods, the smaller farms will utilize their household resources by finding off-farm work. Obtaining an off-farm income stream is the most common method of diversifying income sources (Gertler, 1996). Off-farm income is a significant portion (often the majority) of total income of small farms (Pope and Prescott, 1980). This will likely introduce time constraints that prevent any opportunities to diversify the farm operation (Brown, 1989; Gertler, 1996). Such a course of action is not necessary, even if the operator is so inclined. Indeed, total income (including off-farm income) of small and medium farms often exceeds that of large farms and non-farm families (Gardner, 2002, p. 78; Schmitt, 1991).

Those farms with off-farm income are diversified in the view that is popular with European researchers. They are part-time farmers engaged in pluriactivity. As final questions of interest: Does a farmer view the off-farm job as a risk-reducing function that provides a backstop in case the farm operation fails to provide adequate income? Or, is the off-farm job simply held to finance the capital investments needed to keep pace with technology and the demands of specialized farming? The difference is subtle but reveals the true nature of the farmer. If the off-farm job provides such a significant source of income, the layman would advise ditching the farm operation and investing full-time in a non-farm career. The layman fails to recognize the primacy that the farm operation holds in the farmer's mind. Almost surely, off-farm work is given secondary billing. Its role is to infuse capital into an agricultural operation that is becoming increasingly technological and specialized.

Theory says specialization is driven by technology, agronomics, and transactions costs. The next three chapters will elucidate the situation by applying the ideas of this chapter to Iowa agriculture of the past century. This will be done primarily through empirical measures of Iowa farm diversification throughout the 20th Century. These will be supplemented by case studies and an econometric test.

CHAPTER 3. IOWA FARM DIVERSIFICATION FROM 1885 TO 1997 EMPIRICAL MEASUREMENTS

Diversification is defined for purposes here as the distribution of resources among farm enterprises. This chapter presents the indices of diversification that measure its changes through the last century. The methodology of constructing the indices is first described. Next, the results are presented in several graphs. Finally, the chapter concludes with a brief discussion of the results.

A measurement of diversification will consider n enterprises and each one's relative share $p_1, p_2, \ldots, p_n$ of the total enterprise mix. Thus, the first determination to be made is the unit that will form the shares. There are several ways to describe the relative size of an enterprise. Each could be measured by the value of its production (gross receipts in dollars), the value of inputs devoted to it (again, in dollars), the number of acres uses in its production, and the number of farms that include it in their enterprise mixes.

Each description has its pros and cons. The share of farms undertaking an enterprise is simple and easily interpreted. For example, one could find the percentage of farms producing a group of commodities, say every commodity produced on at least 10% of farms. This is conducive to examining a select group of enterprises over time. The drawback is that it is a crude measure. There is bound to be overlap because farms have heterogeneous enterprise mixes. Counting the number of farms raising corn captures farms that raise different combinations of corn, soybeans, hay, cattle, etc. As a result, it is not easily converted into an overall index of diversification that will be viable empirically or testable econometrically.

The number of acres in each enterprise is also simple. There is no overlap because it is commodity specific. An acre devoted to corn is the same as an acre devoted to wheat. Hence, it is more easily converted into index form. However, it is not an ideal measure for all types of enterprises. Livestock such as hogs and poultry are raised in confinement, pasture, or small areas in general. An acre of corn production is a poor comparison to an acre of hog production because it does not reflect relative output shares.

A measure of inputs devoted to each enterprise is advantageous in that it is comparable across all enterprise types. Dollars spent on hog production can be compared with dollars spent on corn production. The disadvantage in using inputs is the difficulty of deciding what constitutes an input. In the year 1900, would the cost of growing oats be included as an input cost for corn production since the oats were fed to horses that pulled the plow in the corn field? A dollar spent on corn production in 1900 is quite different from one spent in the year 2000 for the same purpose.

The final candidate, value of production, is the most robust[2]. It is centered on output, which, unlike inputs, does not change over time. A bushel of corn in 1900 is the same as in 2000. It is also comparable across enterprises. Value of hog production is comparable to value of corn production because output prices are used to weight the production. In certain productivity indices, changes in relative prices over time will cause problems (Gardner, 2002, pp. 34-46). A diversification index does not suffer this setback because it is concerned with relative shares of output at one point in time, not a productivity in sum. The value of enterprise production in gross receipts will be used to calculate the diversification indices.

The next step is to determine which enterprises to include in the basket for measurement. Table 3.1 presents the 26 enterprises used in this study. They represent all

TABLE 3.1 Iowa farm enterprise list

Corn (harvested for grain)	Soybeans	Mules, Donkeys, Burros
Corn (harvested for silage)	Potatoes and Sweet Potatoes	Cattle
Wheat	Popcorn	Swine
Oats	Field Seeds	Sheep, Lambs, Wool shorn
Barley	Alfalfa	Goats and Kids
Rye	All Other Hay	Poultry and Poultry Products
Flax	Vegetables	Bees and Honey Produced
Buckwheat	Value of Fruits and Nuts	Dairy Products
Sorghums	Horses and Colts	

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[2] Net income would be an even better measure of value of production. For example, see Pope and Prescott (1980). However, this data is not included in the Census of Agriculture.

crops, livestock, and bundles of agricultural products that have been important for at least a part, if not all, of Iowa's agricultural history. All 26 enterprises are used in each year that the indices are calculated. Essentially, an Iowa producer has the choice to include any combination of those 26 enterprises into a diversified/specialized farm portfolio. The indices will allow one to see how the portfolio has changed over time.

The ideal data source for such a project would be detailed survey results from individual Iowa farms going back on a yearly basis into the 19th Century. Such data is not available. The most detailed agricultural data source available is the Census of Agriculture. It has been conducted roughly every five years since the late 19th Century. Surveys concerning nearly all aspects of agriculture are sent to agricultural producers. The results are aggregated to the county and state levels. It is the primary data source for the production and price data required to calculate the value of enterprise production. Consequently, the index values are reported roughly every five years, covering the period 1885 to 1997. (See Appendix A for a detailed discussion of the data treatment.)

As stated, production data from individual farms would have been ideal. Each time data is aggregated, information is lost. Farm enterprise data aggregated one step to the county level should still provide a very good handle on changes in diversification. The indices were calculated for nine Iowa counties, one in each of the crop reporting districts used by Iowa Agricultural Statistics. The choice of each county was fairly arbitrary. The county with the ten-year average corn yield (1991-2000) closest to the average yield for the district was chosen to represent that district. Figure 3.1 shows the location of the nine counties. Two indices were calculated for each county. They are the entropy index and the Hirschman-Herfindahl Index (HHI).

Entropy

Entropy is a concept from information theory. It was pioneered by Shannon (1948) in the seminal work "A Mathematical Theory of Communication". The econometric applications were brought to light by Theil (1971, pp. 631-62) in *Principles of Econometrics.*

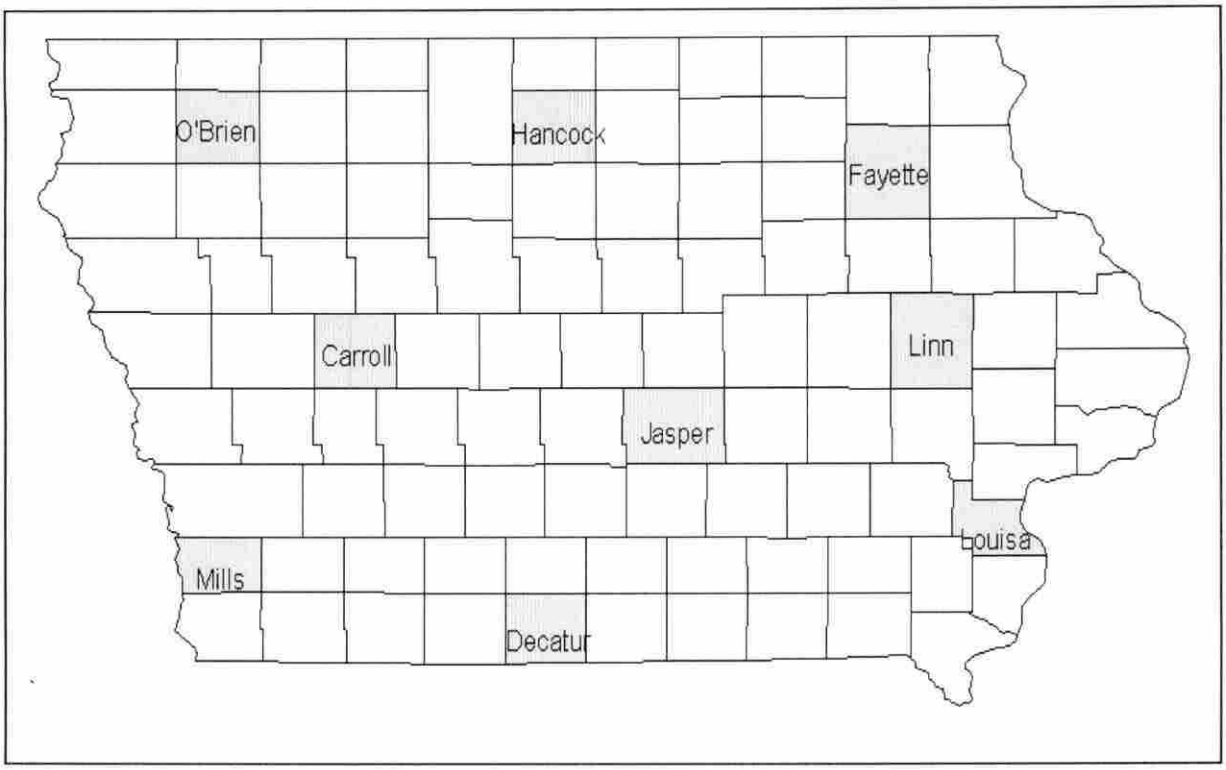

FIGURE 3.1 County Locations

The basic theory is as follows. Let a random event E occur with probability p. If a message is sent communicating that E occurred, then entropy measures the amount of information carried by the message. An event with high probability will cause little surprise when the message states that it has occurred. There is little information in such a message. The reverse is true with a low-probability event. Intuitively, the information measure is a decreasing function, the simplest being

$$h(p) = \log(1/p)$$

which spans from a value of 0, corresponding to a certain probability of 1, to a value of ∞, corresponding to a probability of 0. There is no surprise and no information with a sure outcome, but infinite surprise and infinite information when an outcome has zero chance (Theil, 1971, pp. 636-37).

Theil (1971) demonstrated the theory's applicability to any distribution of several events. He pointed out that events and their probabilities are equivalent to the decomposition of a given total into nonnegative parts, or shares. It has useful functions across several disciplines, including physics, psychology, and the life sciences (Hackbart and Anderson, 1975). Hence, entropy becomes a measure of a distribution's spread, precisely what is needed for measuring diversification of farm enterprises.

The entropy function has several well-behaved properties. It is continuous and conditional on n, $p_1, p_2, \ldots, p_n$ only (Hackbart and Anderson, 1978). It is symmetric, determined by the relative magnitude, not the order, of the p's (Hackbart and Anderson, 1978). Furthermore, it has the convenient property of additivity (Hackbart and Anderson, 1978). Consult Theil (1971, pp. 636-37) for a complete discussion.

The specific form used for this thesis is the entropy measure

$$-\sum_{i=1}^{n} p_i \log (p_i)$$

where p_i is the enterprise share and the log is base 2. Its maximum value is reached when diversification is perfect, or $p_1 = p_2 = \ldots = p_n = 1/n = \log n$ (Hackbart and Anderson, 1975). Its minimum value is 0, which occurs if one $p_i = 1$ while all other p_i's = 0 (complete specialization) (Hackbart and Anderson, 1975). When a $p_i = 0$, the function goes to 0 in the limit

$$\lim_{p \to 0} p \log (p) = 0$$

(Hackbart and Anderson, 1975). This places the entropy measure on a scale of 0 to log n. In order to bound it between 0 and 1, all values were normalized by dividing log 26 into each year's index value. The result is a time-series realization spanning 1885 to 1997 for each county. The nine counties were averaged to obtain a realization for the state.

The Hirschman-Herfindahl Index (HHI)

The HHI is quite well-known for its function in measuring industry concentration. It is commonly interpreted as a proxy for market power. Similar to entropy, it has also been adopted as a measure of economic diversification (Pope and Prescott, 1980). It is a simple function, specified as

$$\sum_{i=1}^{n} p_i^2$$

where the p_i's are the same 26 enterprise shares used in the entropy measure. It is bounded by 0 and 1. In studies of industry concentration, it is often multiplied by a constant, c (generally c = 10,000). Here, it is left in the 0 to 1 range to make it consistent with the entropy scale.

The HHI also has desirable properties that make it an effective concentration index. An empirical relation known as Zipf's law states that, first, ranking a group of *n* shares in non-decreasing order by size, then, multiplying a power of the rank by the size of each share, will produce a constant for the entire group (Naldi, 2003)[3]. In notation form, it is

$$r^{\alpha}\, p_i = \text{constant}$$

in which r represents the rank, p_i is the size of the i^{th} share, and the power term, α, is Zipf's parameter. It is descriptive of unbalanced distributions of many economic quantities. The parameter, α, is a concentration indicator. The larger its value, the greater is the imbalance in the distribution (Naldi, 2003). An index should be sensitive to different degrees of unevenness in a distribution, or different values of α. Naldi showed that the HHI is able to sharply resolve (and magnify) even slight variations in a distribution, provided the economic quantity can be represented by Zipf's law. This suggests that the HHI is a good tool to capture the variations in the balance of a farm enterprise distribution, or changes in diversification over time.

The HHI was calculated using the same data as the entropy measure. Again, it was calculated for each of the nine counties, with the counties averaged to yield an HHI realization for the state. The results of the two measures are presented next.

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[3] Consult Zörnig and Altmann (1995) for a complete description of Zipf's law.

Results[4]

Recall that as diversification decreases (meaning specialization increases), entropy is a decreasing function while the HHI is an increasing function. Examining Figure 3.2, one can see that each measure shows increasing specialization in Iowa over the last century. The entropy chart is roughly concave. Diversification appears to experience a small increase from 1885 until it peaks in 1930. It then decreases in a relatively steady, linear fashion, jumps a bit at 1982, then resumes its decline to the extent of the data. The HHI chart is slightly convex. Diversification remains flat until 1935, after which a specialization trend occurs in a steady manner. The individual county charts of Figures 3.3-3.11 reflect the same patterns, with the peaks, valleys, and bumps present in varying degrees.

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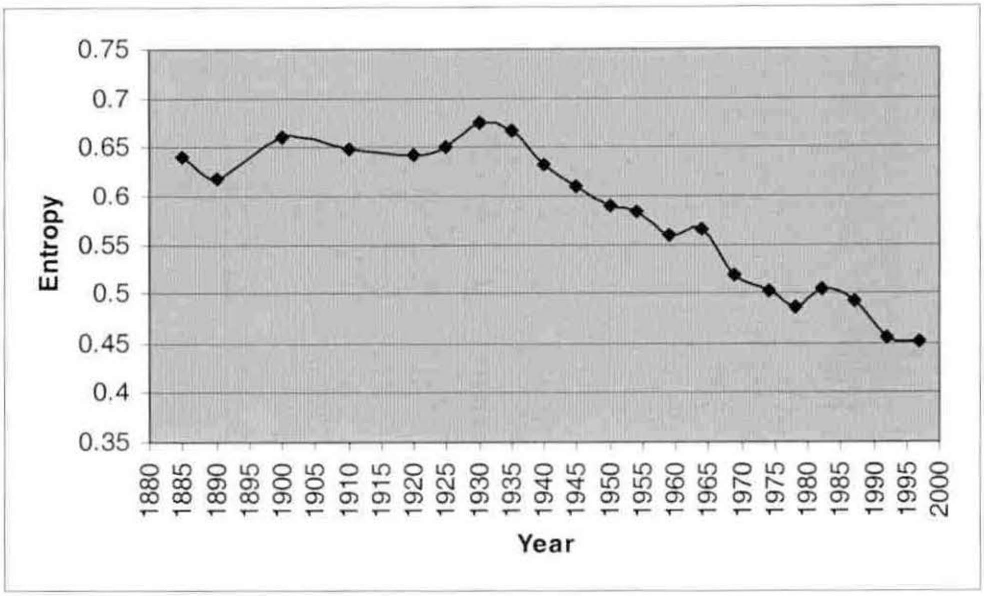
[4] The indexes were also calculated using constant, 1997 prices. Consult Appendix B.



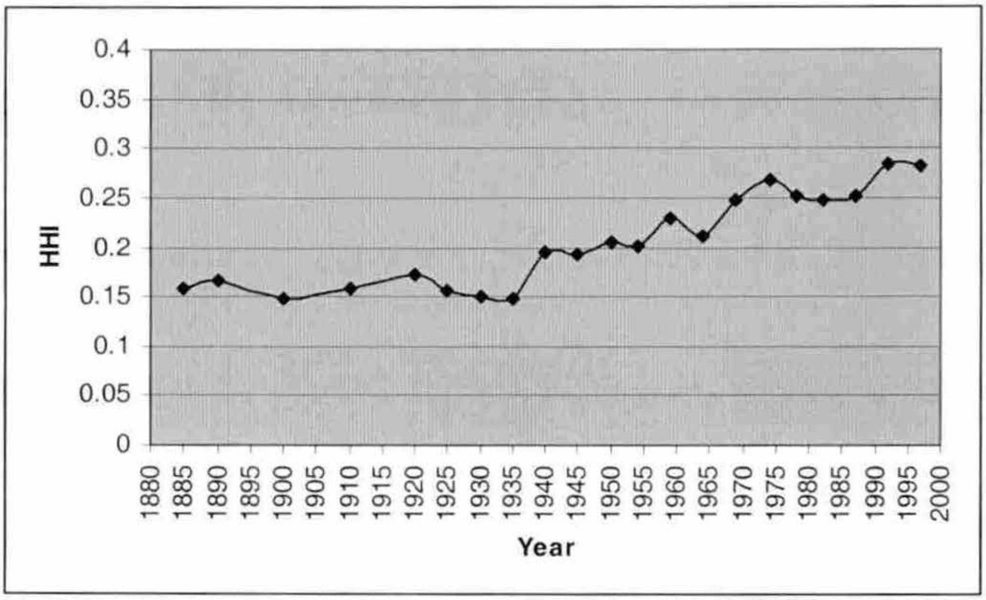
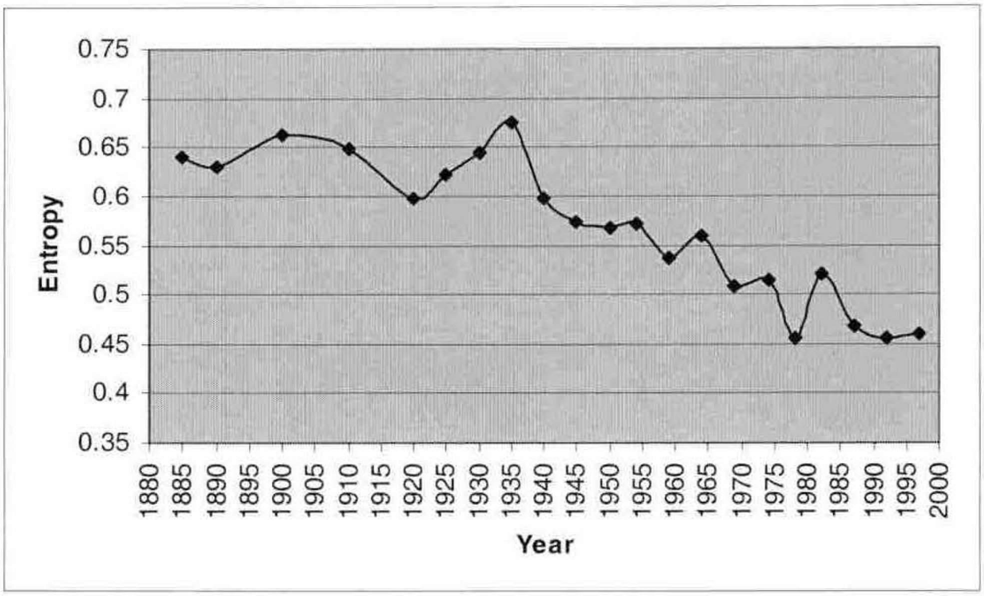


FIGURE 3.2 Nine-county average indices



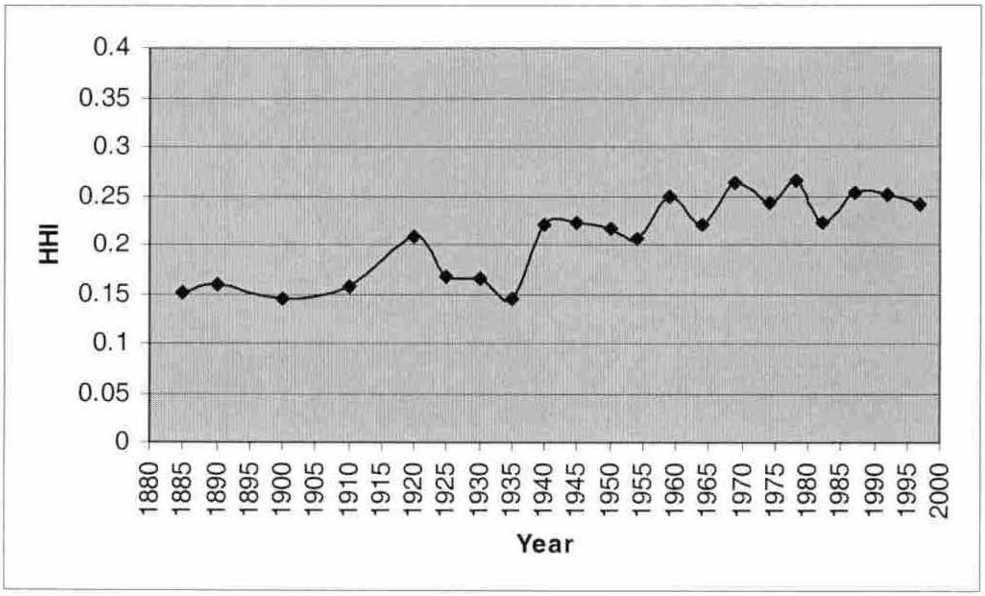
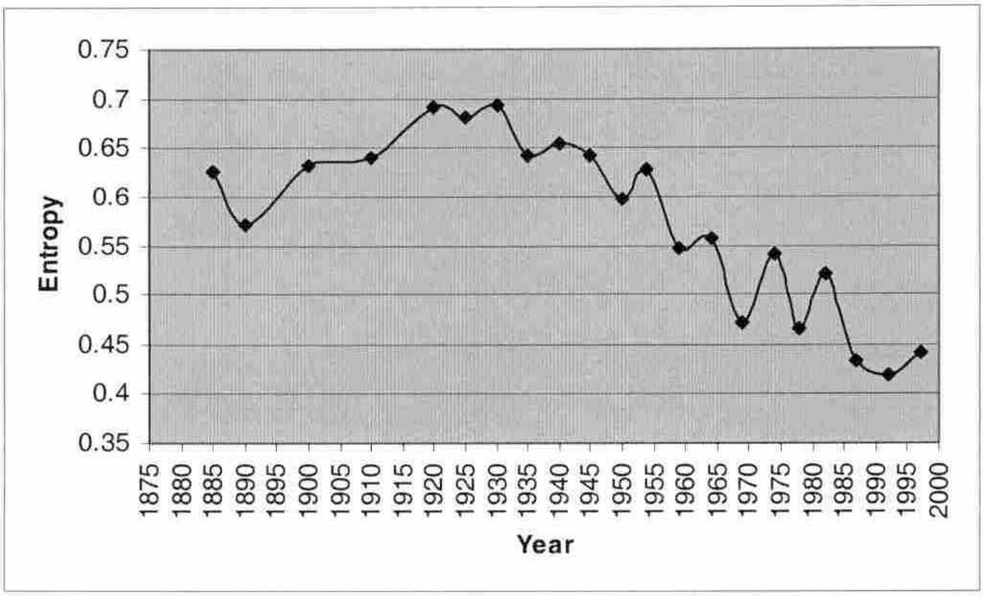


FIGURE 3.3 Carroll County



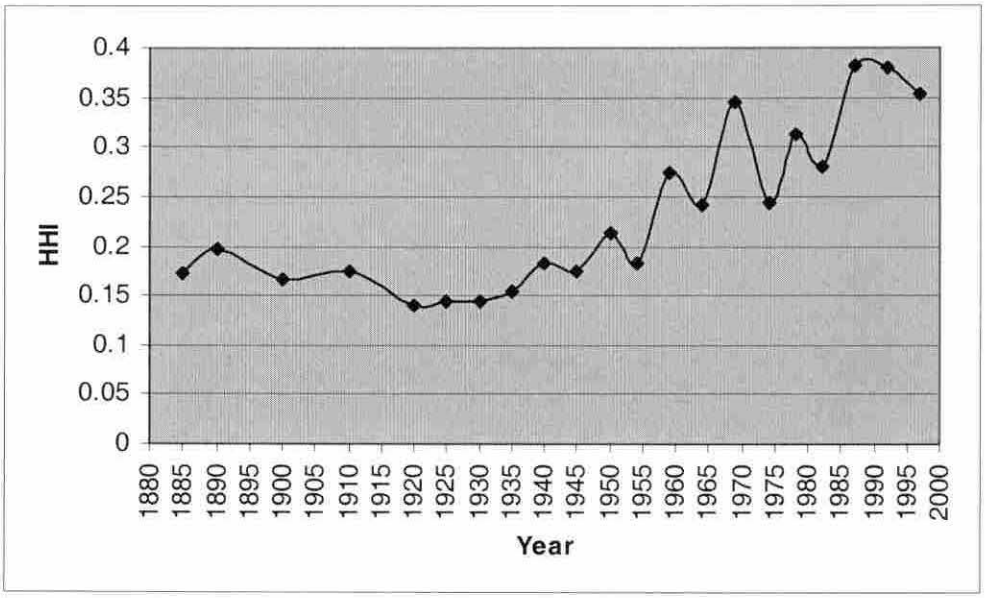
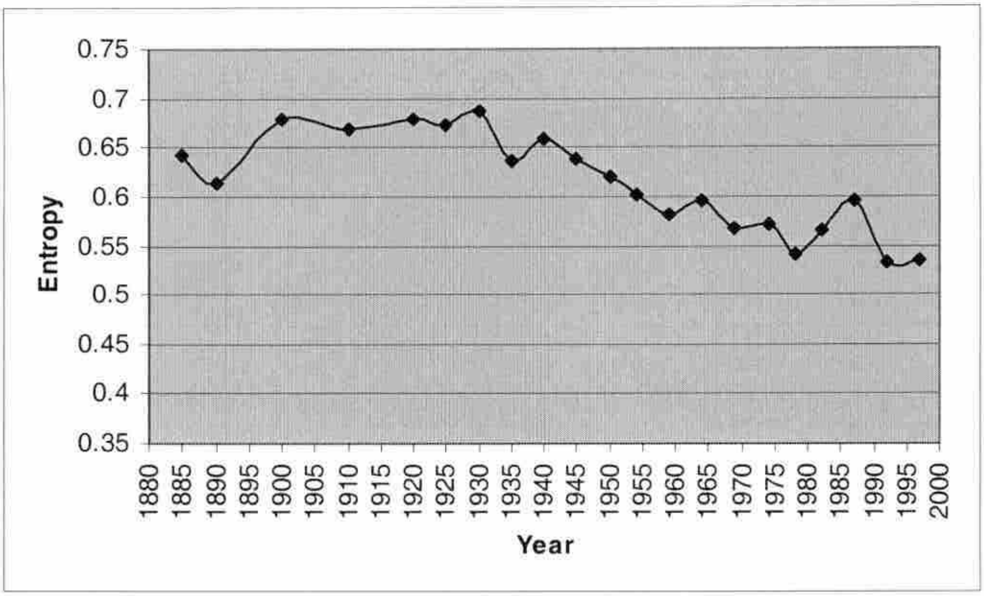


FIGURE 3.4 Decatur County



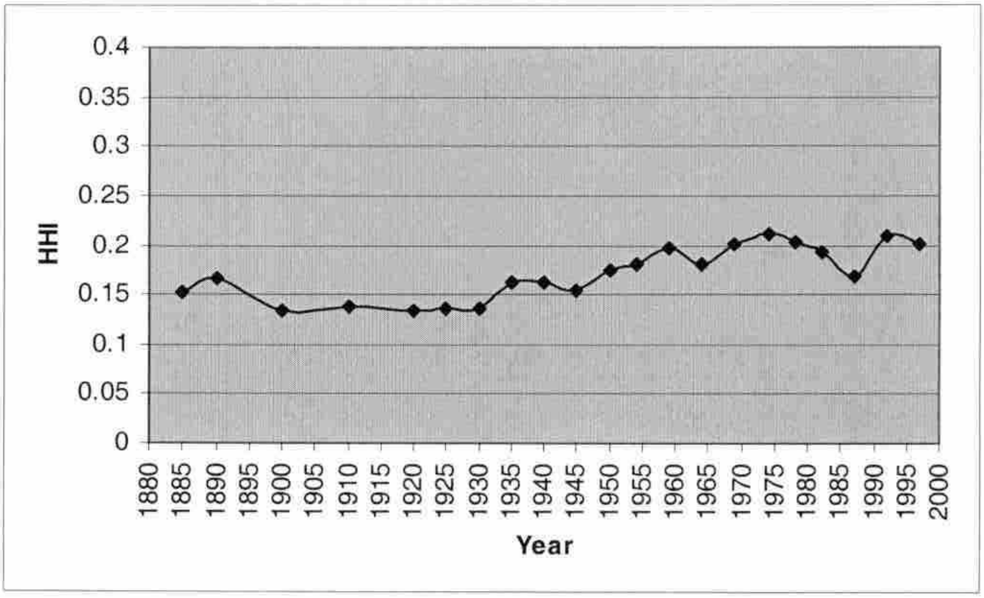
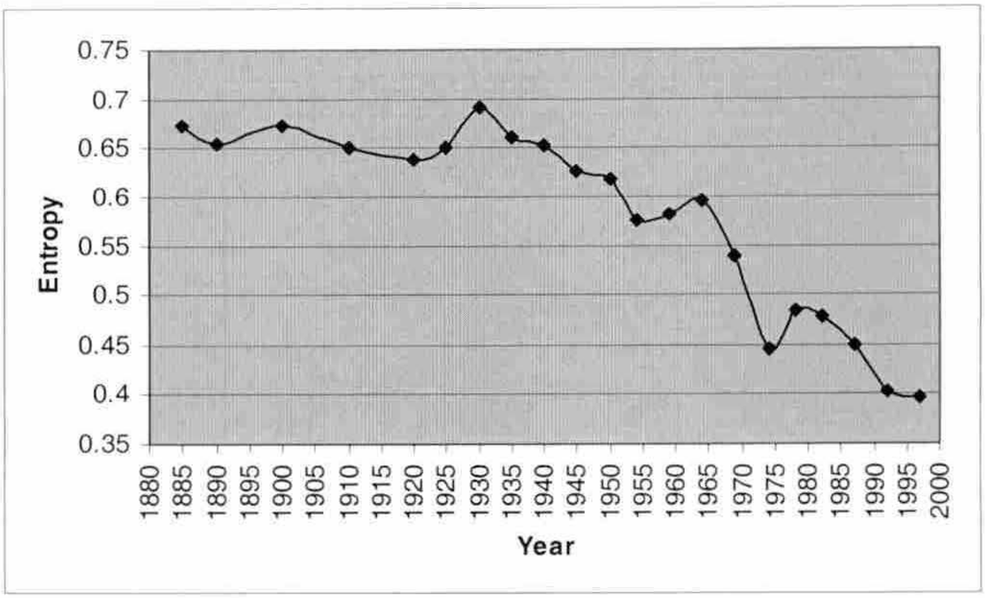


FIGURE 3.5 Fayette County



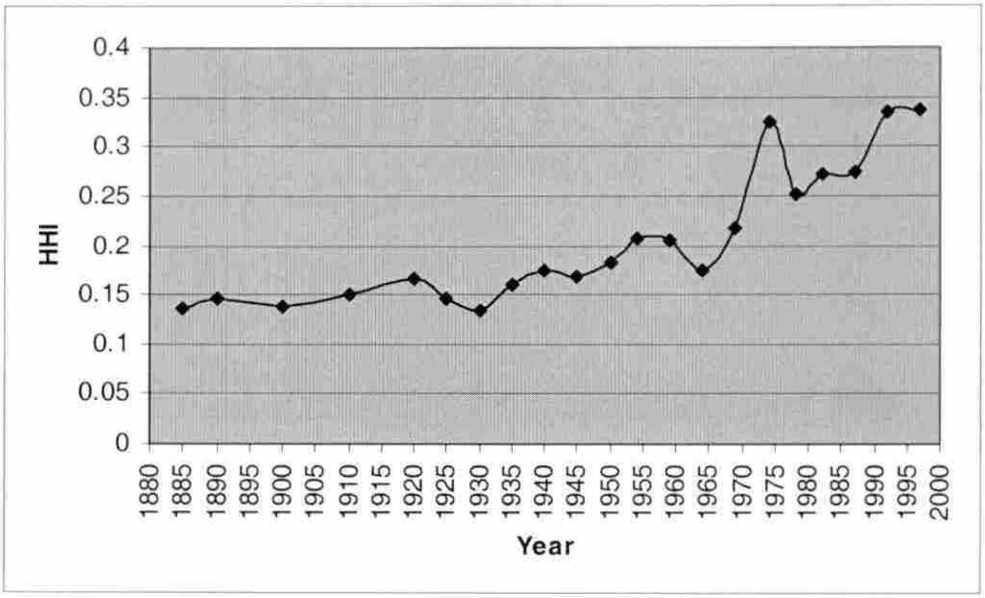
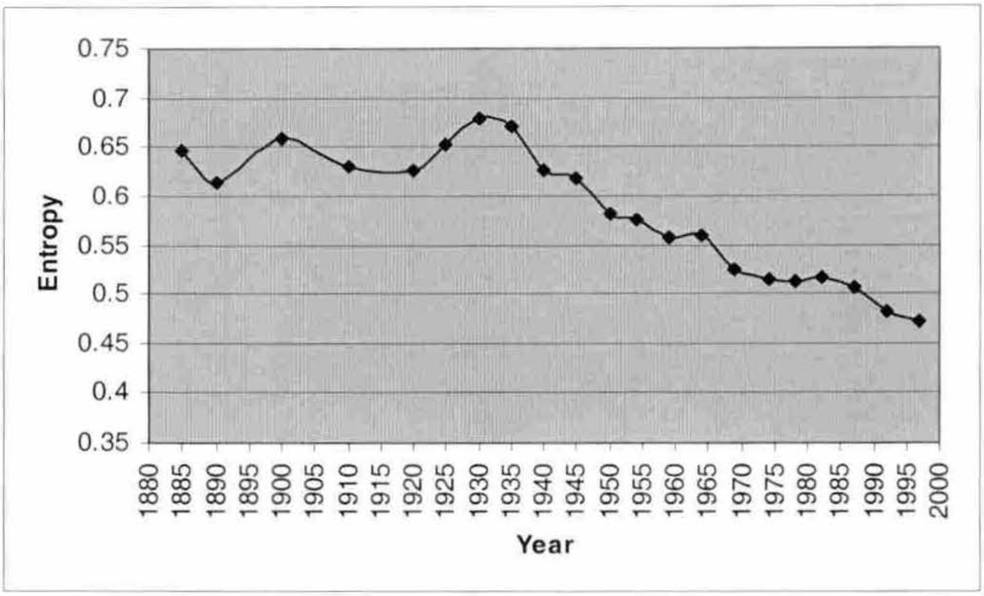


FIGURE 3.6 Hancock County



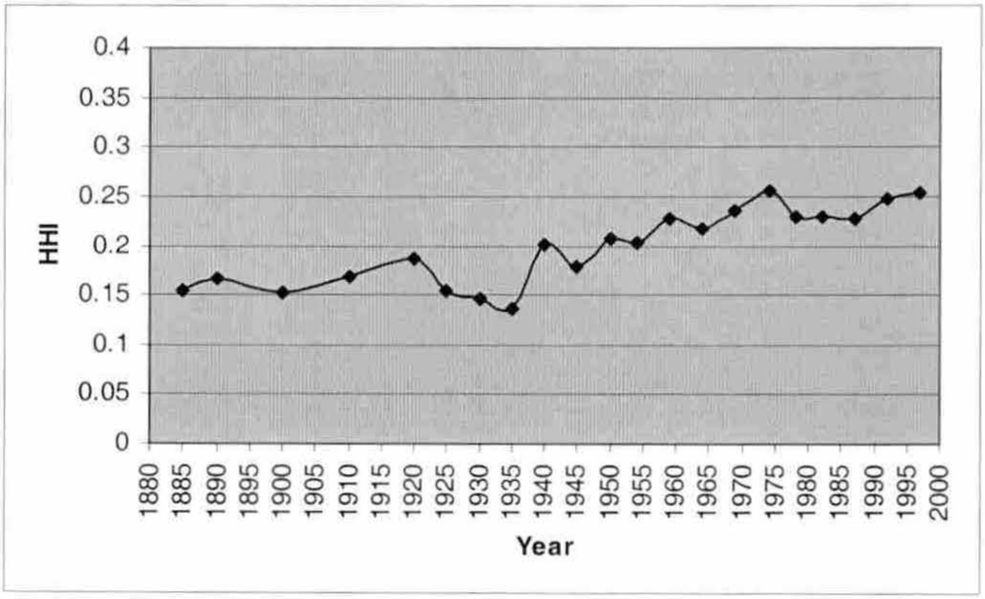
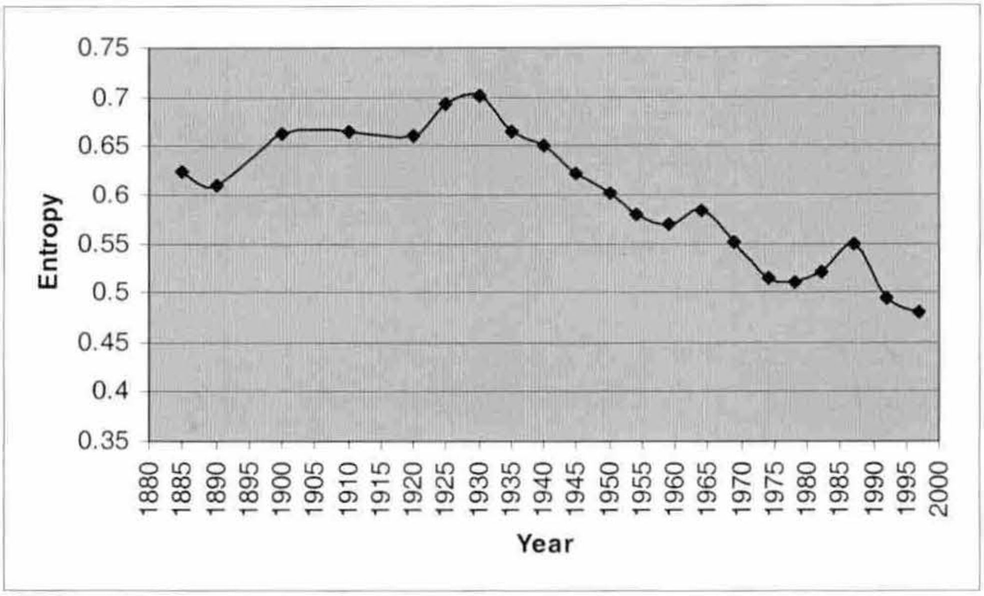


FIGURE 3.7 Jasper County



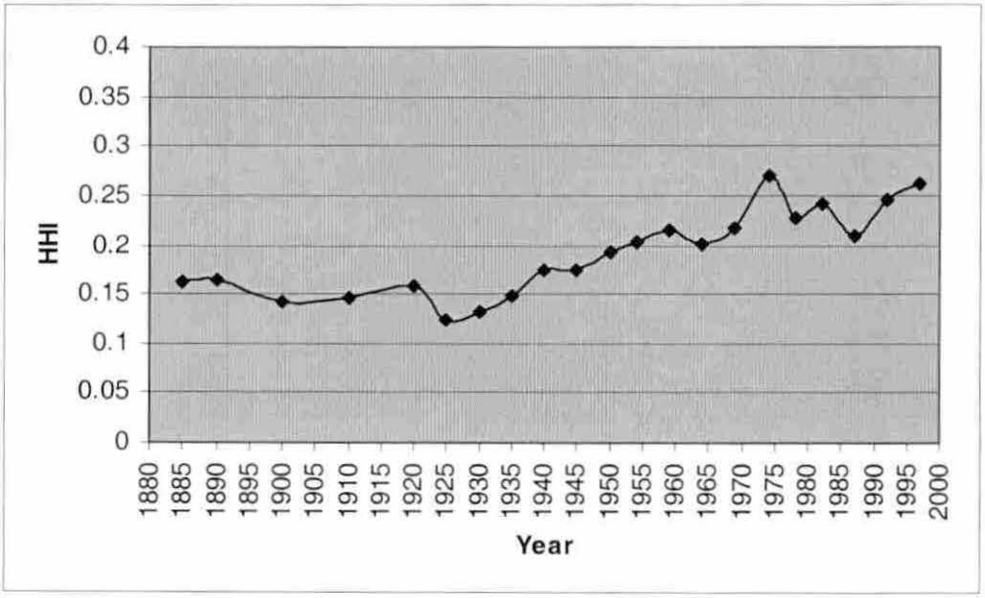
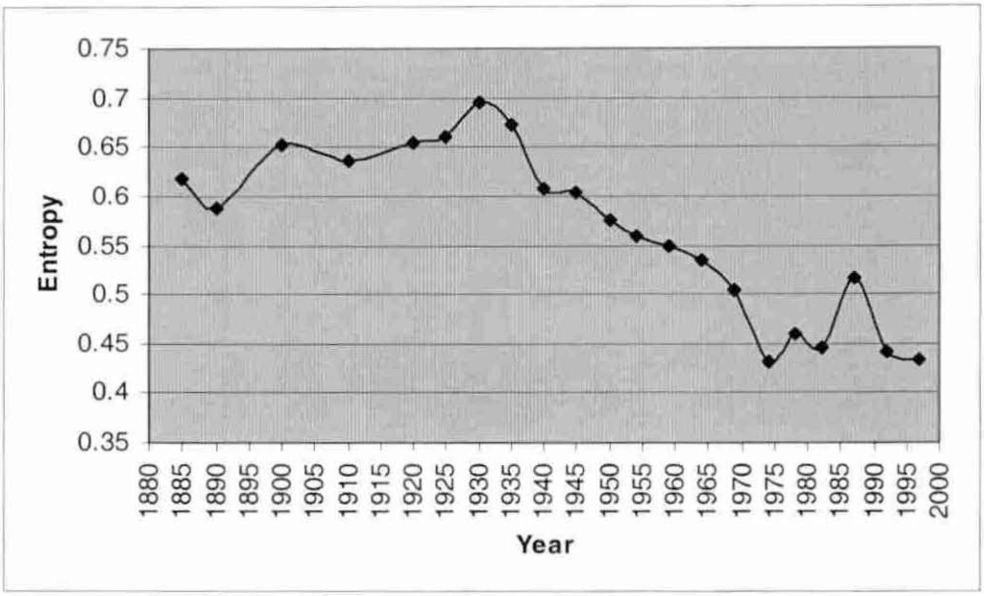


FIGURE 3.8 Linn County



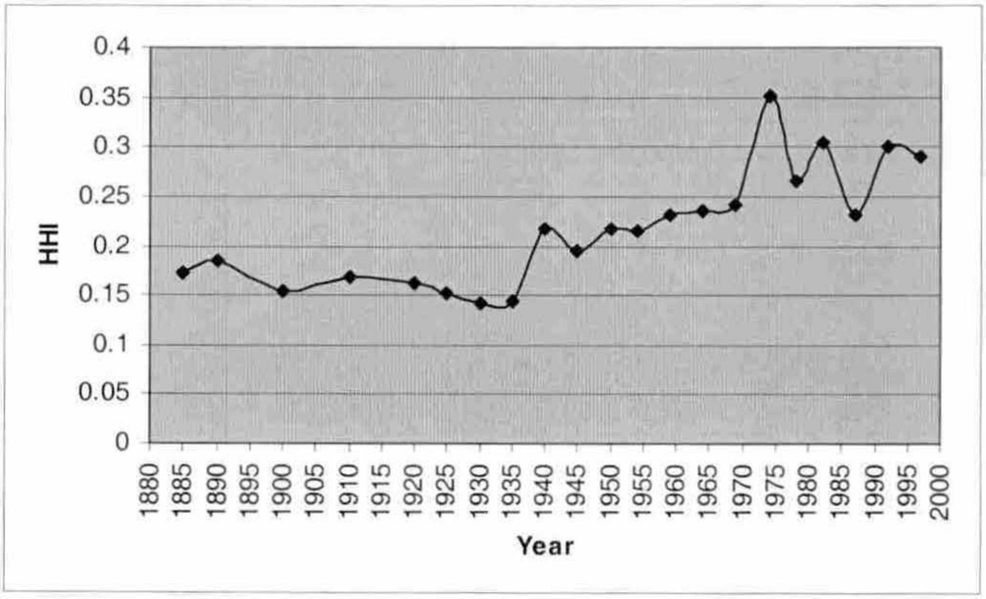
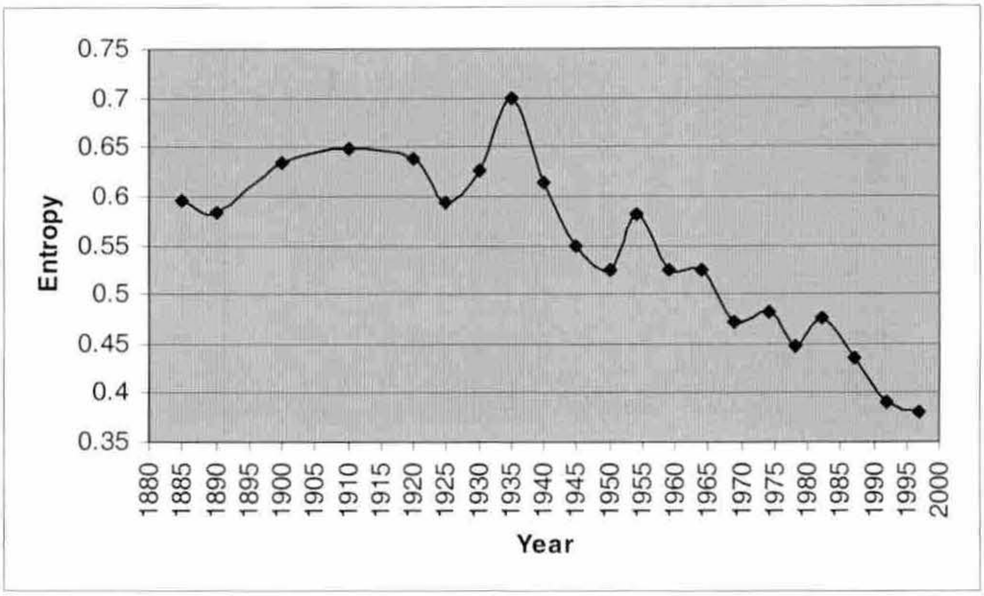


FIGURE 3.9 Louisa County



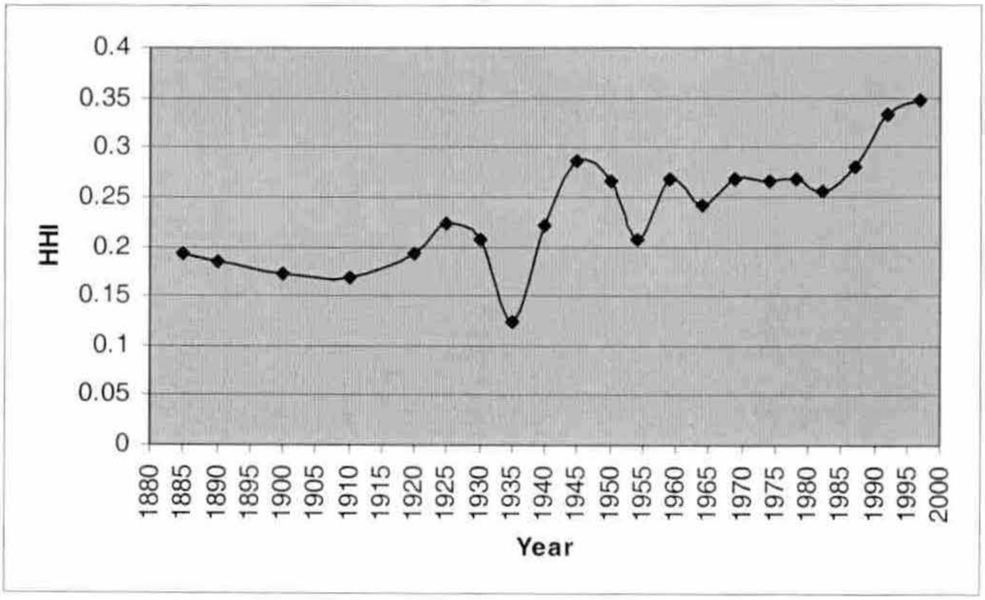
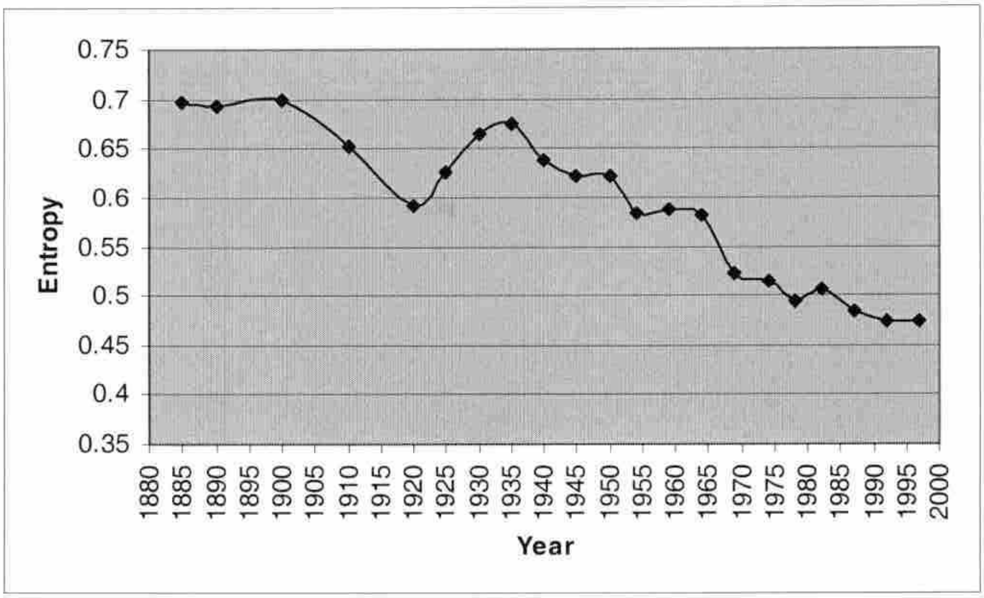


FIGURE 3.10 Mills County



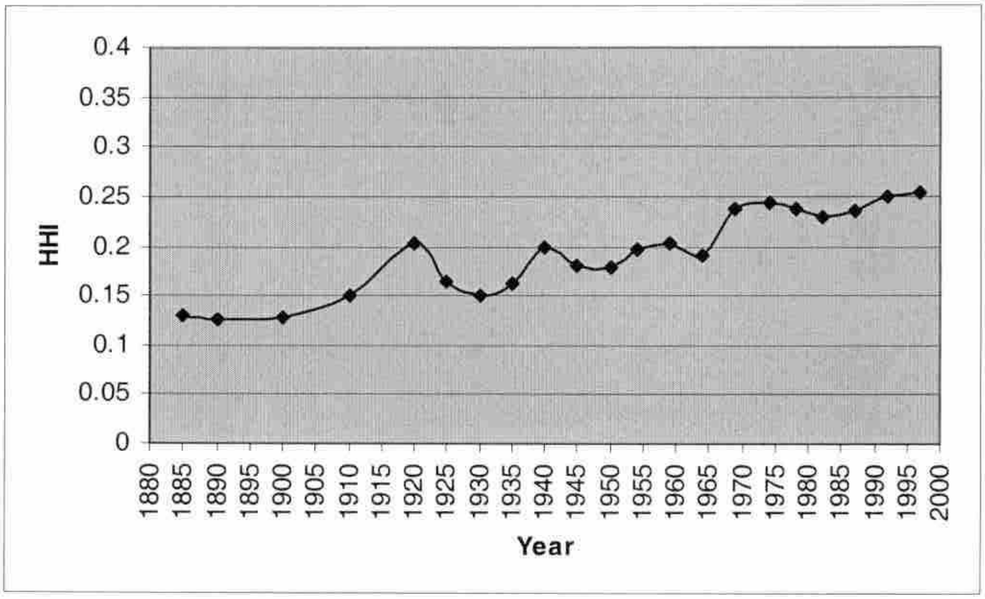


FIGURE 3.11 O'Brien County

CHAPTER 4. CASE STUDIES OF IOWA AGRICULTURE

Hybrid Seed Corn

Three major changes have occurred in Iowa agriculture over the past century. Each change has centered on a particular crop or type of enterprise. The first one took place in corn production. Hybrid seed corn was developed in the 1930's; 90 percent of all Iowa corn grown in 1940 was a hybrid variety (Clarke, 1994, pp. 166-170). Also, the tractor and the mechanical corn picker became viable options in corn production at that time (Clarke, 1994, pp. 170-181).

The stage was set for these innovations by the establishment of a system of public agricultural research (Clarke, 1994, pp. 28-33). The United States Department of Agriculture (USDA), state land grant universities, state experimental stations, and university extension took over research in the agricultural sciences and the application of mechanical technology developed by private manufacturers (Clarke, 1994, pp. 44). From 1920 onward, agricultural innovation was largely the result of theoretical research conducted by the public system (Clarke, 1994, pp. 44). Farmers were relegated to adopters of technology, not innovators (Clarke, 1994, pp. 44).

There exists a school of thought that public researchers, extension personnel, and the agro-industry have encouraged farmers to specialize their production, seek economies of size, and depend on purchased inputs (Clarke, 1994, p. 45; Gertler, 1996; Shucksmith *et al*, 1989). The more conspiratorial mind will state that this is purposefully done to increase the profits of implement dealers and chemical input suppliers at the expense of farmers. Regardless of one's stance on the issue, it would seem that the nature of the new technology encouraged specialization. The hybrids drastically improved corn yields. Chemical fertilizers, herbicides, and pesticides removed the need for an extensive crop rotation. Tractors and mechanical corn harvesters introduced economies of size. It is obvious an Iowa farmer would grow as many acres of corn as possible. In fact, Clarke calculated that the market price of corn would have to drop to 12 cents per bushel for an investor in hybrid corn to incur a loss during the late Depression years (Clarke, 1994, p. 168).

A related question is posed by Gardner (2002, p. 18): Is technological innovation "induced" by economic conditions, or is it the result of autonomous research and development? In this context, the hypothesis says the technological research of the public system developed autonomously and caused specialization at the farm level. This will be econometrically tested in the next chapter. Until then, there are two other clues to investigate.

The first clue is Clarke's (1994, chapters 4, 6) threshold model for tractor adoption. Clarke calculated an acreage threshold[5]. In 1929, 72.1% of all Iowa farms had enough acreage to make a tractor's cost savings adequate relative a team of horses; yet, only 29.4% of farms had tractors (Clarke, 1994, pp. 93). In 1939, 71.5% of farms exceeded the acreage threshold, but 55.3% of farms had tractors (Clarke, 1994, p. 176). Though conditions were sufficient, farmers were slow to adopt.

Once the new machines were adopted, farmers certainly had incentive to capture economies of size in corn production. As the theory states, this should prompt specialization. One would expect this to occur during the 1930's as hybrid seed and mechanization became quite prevalent. Indeed, the county charts reflect this. The trend is especially evident in Carroll, Jasper, Linn, and Louisa Counties. These counties have soils that produce good yields. This second clue supports the hypothesis.

The Advent of Soybeans

The second major change in Iowa agriculture was the introduction of soybeans. Originally grown as a hay crop, it was soon discovered that the meal and oil were valuable end products (Windish, 1981, p. 2). It had even greater value to Iowa farmers as a second crop in a corn-soybean rotation. European corn borers became a menace in the 1920's (Windish, 1981, p. 2). Chich bugs invaded in the mid-1930's, devouring everything green

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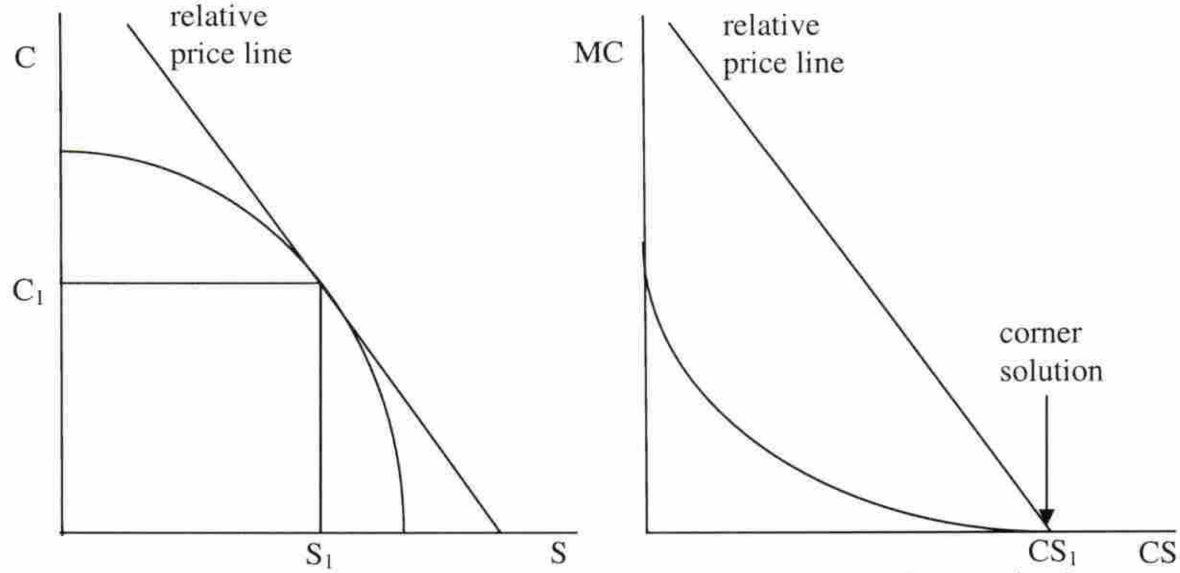
[5] Threshold models are various in form. Readers interested in early farm adoption of tractors or similar technology are encouraged to consult Lew's (2000) excellent paper on a threshold model using real options that models tractor adoption on the Canadian prairies.



a. soybeans prompt specialization among corn C_1 and soybeans S_1

b. soybeans give the corn/soybean rotation CS_1 an advantage over a multiple-crop rotation MC

FIGURE 4.1 Effect of soybeans on diversification

except soybeans (Windish, 1981, p. 3). Soybeans proved to be resistant to those pests. They transformed a troubled, continuous corn rotation into a sustainable, two-crop rotation. A PPF of corn and soybeans will be concave, giving a solution of diversification into both crops (Figure 4.1a)

In the long run, corn and soybeans have become complementary products. Corn yields have increased substantially, aided at least in part by rotation with soybeans. It is important to note that two complementary or supplementary enterprises will experience less reduction in variance of returns than two independent enterprises (Heady, 1952). However, farmers do not grow soybeans to reduce income variance. Rather, they are grown to increase returns. Analytically, any range of complementarity in a PPF will promote returns from diversification between the two products.

Soybeans first appeared in the Census in 1925. There was a surge in production from 1940 to 1945. One should see an increase in diversification during that time. The HHI captures this, showing a dip in the chart at 1945 for every county except Mills and Carroll. The entropy index, however, shows a continuing trend of specialization for every county except Louisa. The evidence is mixed.

After 1945, the corn-soybean rotation would seem to further encourage specialization. Global demand for the products of the soy complex has surged. This has lifted prices into profitable territory. As a sustainable, profitable crop rotation, it has come to dominate crop production. No other crops are necessary for rotational benefits. Capital inputs for planting, fertilizing, and harvesting both crops are similar, or enterprise specific. A soybean header for mechanical harvesting was available as early as 1930 (Windish, 1981, p. 56). If one draws a transformation surface for different crop rotations and a price line for relative returns of different rotations, the factors listed above will generate a convex surface and a corner solution (Figure 4.1b). One should see increasing specialization after 1945, which is in fact observed in all counties except Mills and Carroll. These counties show the trend starting after 1954.

The Industrialization of Livestock Production

The third major change in Iowa agriculture has been the restructuring of the livestock industry over the past fifty years. As explained in chapter two, livestock production has become industrialized. The hypothesis says this will increase specialization at the farm level. The specialization trend is quite evident in all counties since mid-century. Unfortunately, the charts cannot separate the magnitude that each effect has on specialization. The effect of soybeans versus factory hog production versus improved harvesting machinery, and so on, cannot be gauged.

The Census does not separate the family-operated farm from the large, industrialized factory farm in its surveys. A survey is sent to all "places" of agricultural production. Therefore, the full effect of industrialized livestock production in the family farm is probably not reflected in the diversification indices. It is a regrettable limitation of the data.

A final question of interest is the impact of major macroeconomic events on diversification. The evidence is ambiguous. It is unfortunate that a Census was not taken in

1915, which would have enabled a comparison with 1920 to test the effects of World War I. As it is, some of the charts show increased specialization between 1910 and 1920, some show increased diversification, while still others show no change. Any impact of the Great Depression and World War II would be mixed with, and likely overshadowed by, the effects of rapid technological advances of the time. It is possible to pick out the surge in grain prices and relatively weak cattle prices during the 1970's. This caused many producers to sell their cattle herds and concentrate on grain production (Gertler, 1996). The central and eastern counties have spikes of specialization at 1974, while the spikes occur at 1978 for western counties.

The only notable standout among the nine counties is Fayette. It has seen a specialization trend, but not nearly as great as the other counties. The cause can be traced to its dairy production. It is located in a dairy region, the far northwest corner of the state. Dairy production is still very much a family operation. The hand of industrialization has not touched it nearly as much as other livestock enterprises. It is an operation that needs hay and forage crops. By nature, it is a more diversified system of farming.

CHAPTER 5. AN ECONOMETRIC APPLICATION
THE GRANGER TEST

This chapter details an empirical test of the hypothesis that technological advance has driven the trend of specialization observed in Iowa. Recall the question raised by Gardner: Is technological advance drawn forth by the economic environment, or is the economic environment shaped by technology? In this specific case, a test is needed to discern among four alternatives: 1) technological advance has driven farm specialization, 2) farm specialization has induced technological advance, 3) the two variables interact, with feedback between them, or 4) there is no causality relationship between them. The Granger test of causality is ideally suited for such a question. Granger (1969) proposed explicit definitions of causality and feedback. The definitions were also proved to be testable, making them quite useful. The tests were eagerly adopted by monetarists to investigate the relationship between money supply and other macroeconomic variables[6]. Here, the test is translated into an agricultural setting. If specialization is found to cause the technological advance, this suggests that technology did not drive specialization. Rather, other factors assume the causal role, factors which encouraged specialization and induced the technological change.

<u>Technical Discussion</u>

The basic idea behind Granger causality is predictive accuracy. Let X and Y be covariance stationary time series within the universe U. All information from time $t - 1$ is represented by U_t, while $U_t - Y_t$ is all that information except the series Y_t. Using these definitions, y_t is said to cause x_t if a prediction of x_t using all information U_t is superior to a prediction using all information except Y_t, or $(U_t - Y_t)$. Formally, if $\sigma^2(X|U) < \sigma^2(X|\overline{U - Y})$, then Y causes X, or $Y_t \Rightarrow X_t$ in notation form (Granger, 1969). The better predictor is revealed by the smaller σ^2, which is the minimum prediction error variance.

Most of the information in U_t will not affect the causal relation, $Y_t \Rightarrow X_t$. Often, U_t will be collapsed to a bivariate vector space containing only X_t and Y_t. The causal definition is then modified: if $\sigma^2(X|\overline{X}, \overline{Y}) < \sigma^2(X|\overline{X})$, then $Y_t \Rightarrow X_t$. Intuitively, it is easy to see that

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[6] See, for example, Sims (1972) and Nelson (1979).

$Y_t \Rightarrow X_t$ if X_t can be better predicted by information including Y_t than by past X_t's alone. This is the essence of Granger causality.

This definition of causality is testable in the following sense: correlation between past values of Y_t and the part of X_t that cannot be predicted from its past indicates the causal relation $Y_t \Rightarrow X_t$ (Sims, 1972). In practice, the Granger test can be executed in a number of ways, depending on how the bivariate time-series model $\begin{vmatrix} X \\ Y \end{vmatrix}$ is represented. See Chow (1983, pp. 212-217) for detailed discussions of the autoregressive, moving average, and univariate representations.

A good intuitive explanation of the test using the moving average (MA) representation is given by Nelson (1979). If X_t is represented in univariate, Wold form,

$$X_t = \psi(L)a_t = \pi(L)y_{t-1} + a_t,$$

then a_t is serially random, or the portion of X_t that past X_t cannot predict. If $Y_t \Rightarrow X_t$, then past Y_t will be correlated with a_t, implying that Y_t is able to predict that which past X_t cannot. In practice, X_t is regressed on current and past Y_t. Correlation between past Y_t and residuals is detected by examining the coefficients on the lagged X terms. Nonzero coefficients indicate correlation, and thus causation from Y_t to X_t.

In the context of this thesis, the "cause" variable, Y_t, is a proxy for technological change in agriculture. The first step in the empirical test is finding an appropriate proxy. Any attempt to capture technological change in one variable is fraught with difficulties. Agricultural technology is quite heterogeneous. The impacts and adoption rates of different innovations are likely to be unequal. For example, how does one compare the impact of a tractor with that of a new farm financial software package? Furthermore, tractor technology itself changes over time.

One solution is multifactor productivity (MFP) indices, which are ratios of aggregate output against an aggregate basket of inputs. However, the economic interpretation of the ratio is fuzzy, as is the aggregate input index. Heterogeneous technology and differing efficiencies among farms (which are heterogeneous themselves) that utilize the technology make it difficult to meet the conditions under which a MFP index is an accurate measure of technological change (Gardner, 2002, pp. 34-46).

The difficulties associated with MFP indices prompted a search for another solution to the measurement problem. Examining the nature of the problem gave some insight. From the farm firm's perspective, technological advance is the ability to generate more output for each input unit required in the production process (Herdt and Cochrane, 1966). The source of increased production must be inputs contributed by an entity external to the farm. A farm will have neither its own research and development (R & D) as a direct source of new inputs, nor access to much private sector R & D as an indirect source of new inputs. This suggests public agricultural research is a good proxy of technological change. Recall from the previous chapter that agricultural research was mostly taken over by the public sector during the early part of the century. The results of that research seemed to encourage specialization. Consequently, the Y_t variable in the test becomes dollars spent on public agricultural research. In particular, it is a time series of total U.S. public research funds geared specifically toward agricultural technology (1888-1995). In this case, "public research" is that done by the USDA and state agricultural experimental stations (SAES). See Appendix C for a detailed treatment of the data.

The "result" variable, X_t, is the measure of diversification, either entropy or HHI. The test was run once with entropy, then again with HHI. These are the time series data sets presented in chart form in chapter three, each of which is the nine-county average. See Appendix A for the raw data and a further explanation of the indices.

Sims (1972, pp. 544-45) has proven the following theorem: "When $\begin{vmatrix} X \\ Y \end{vmatrix}$ has an autoregressive representation, Y can be expressed as a distributed lag function of current and past X with a residual which is not correlated with any values of X, past or future, if, and only if, Y does not cause X in Granger's sense." The Sims test for unidirectional causality thus involves regressing X on past and future Y. If causality flows exclusively from Y to X, the coefficients on the future lags of Y will be insignificantly different from zero. The theorem given above is employed to determine if causality runs from technology to specialization.

Box and Jenkins diagnostics showed that each time-series data set is autoregressive AR(1). The Dickey-Fuller test also revealed that they contain unit roots. The null hypothesis says that there is a unit root. One rejects the null if the Dickey-Fuller value is less than the critical value. The test included a time variable to account for the linear time trend in the data sets. Table 5.1 shows that the test gives values that are greater than the critical value for all three data sets. Thus, one fails to reject the null that they contain unit roots.

TABLE 5.1 Dickey-Fuller values for unit root tests (at 5% significance)

	Spending	Entropy	HHI
Critical Value	-3.410	-3.410	-3.410
Dickey-Fuller Value	-1.791	-1.705	-2.605

The next step was to test for cointigration between the data sets. If two I(1) data sets are not cointigrated, running a regression to test relationships between their levels will lead to spurious results. The cointigration test gave strong indication that spending is cointigrated with neither entropy nor HHI. Again, it was executed in a manner to account for the linear time trend in the data. Table 5.2 shows that one fails to reject the null that there is no cointigration because the Dickey-Fuller values are greater than the critical values.

TABLE 5.2 Dickey-Fuller values for cointigration tests (at 5% significance)

	Spending-Entropy	Spending-HHI
Critical Value	-3.780	-3.780
Dickey-Fuller Value	-2.118	-2.949

Since there is no evidence of cointigration, the next best alternative is to transform the data sets with differencing. First-differencing was applied to each data set before the causality test was executed. Unit root tests revealed that the once-differenced data sets do not contain unit roots. Table 5.3 gives the results. The test values are less than the critical values, allowing one to reject the null that they contain unit roots. This indicates that they are covariance-stationary and appropriate for the causality test.

TABLE 5.3 Dickey-Fuller values for unit root tests of first-differenced data sets (at 5% significance level)

	Spending	Entropy	HHI
Critical Value	-2.860	-2.860	-2.860
Dickey-Fuller Value	-3.232	-5.010	-5.931

Table 5.4 gives the causality test results. If the hypothesis is correct, regressions of the diversification variable on past and future lags of the technology variable should produce future technology coefficients that, as a group, are insignificantly different from zero. An F test is employed to test this. Indeed, all diversification on technology regressions show that this is the case. One cannot reject the null that future coefficients are zero, meaning that diversification does not cause technology. If causation is unidirectional, then regressions of technology on past and future lags of diversification should produce F-test results that allow one to reject the null that future diversification coefficients are zero. This would mean that technology causes diversification. However, that is not so. Table 5.4 shows all groups of

TABLE 5.4 F test results on groups of future lag coefficients

1 Lag Models		**2 Lag Models**	
Regression Equation	$F_{(1,14)}$ Statistic	Regression Equation	$F_{(2,10)}$ Statistic
Entropy		Entropy	
Diversification on Technology	0.033	Diversification on Technology	0.008
Technology on Diversification	0.955	Technology on Diversification	0.899
HHI		HHI	
Diversification on Technology	0.001	Diversification on Technology	0.254
Technology on Diversification	0.102	Technology on Diversification	0.849

future coefficients as insignificantly different from zero. The results do not support the hypothesis of unidirectional causality running from technology to diversification. They fail to detect causality in either direction.

Critical Review of the Granger Test

One must have a bias toward skepticism when interpreting a Granger test. Any definition of causality in general invites argument. Even assuming agreement is reached on a definition, say Granger's definition, there have been questions raised about its real-world applications (Nelson, 1979). Detecting real-world causal relations in an empirical fashion has always been difficult (Chow, 1983, pp. 212). One problem is that a bivariate model disregards information outside the set $\begin{vmatrix} X \\ Y \end{vmatrix}$. A complex situation could have many causes. Thus, Granger causality misses impacts that a multivariate regression could potentially detect. Another problem, pointed out by Granger (1969), is that the speed of information running through the economy and the sampling period of the data will limit the ability of a simple model to describe a causal mechanism.

In concluding this chapter, a two-part discussion to address the concerns about testing the hypothesis with Granger causality is offered. The first part will tackle conceptual issues. The reality of "cause" and "effect" is assumed as a given. With the bedrock assumption stated, the next question is about causal factors. To be sure, there are many causes besides technology that might prompt a farmer to produce a certain enterprise mix. A multivariate regression could pick up on those factors. However, multivariate regression does not reveal causation. The main thrust of this hypothesis is to propose a causal relationship. The Granger test is suited to this purpose. It can also shed light on the debate between the idea that economic conditions spawn innovation versus the thought that autonomous innovation molds the economic environment.

The second part of the discussion concerns operational issues. It is assumed that the test is applicable to the hypothesis. Within this context, the speed with which information runs through the economy is the time between research funds spent on technological innovation and adoption of the innovation at the farm level. This lag time will vary. This is related to the sampling period of the data. The data points are separated by five years. This makes it difficult to match the lags in the regression with the lags in adoption. The sampling points are perhaps too far apart to tease out the intricacies of technology's impact on diversification. It has been demonstrated by Granger (1969) that a unidirectional causal relation can be mistakenly diagnosed as a feedback process if the time elapsed between time series realizations is too long to pick up the details of causality. It is possible that is the case here. If so, that is no fault of the test. Indeed, the nature of the data would hamper any empirical test. Gardner (2002, pp. 276-77) has asserted that hypotheses in agriculture are contingent on crop cycles and even longer time scales. At those time intervals, it would take decades, or even centuries, of data to capture enough cycles that would properly test hypotheses. Operationally, the data sets contain too few observations, too few structural changes, and too many dominating trends for ideal statistical analysis. In short, it is proposed that the Granger test results should be skeptically evaluated because of the type of data used, not the test methodology itself.

The concerns listed above are neither intended to discredit Granger causality, nor to disregard unsupportive test results, but to invite critical thinking about causality and its testability. Hopefully, this critical thinking will lead to further research efforts. The Granger test does not support the hypothesis that technology is driving specialization. The results do not absolutely refute the hypothesis. Future research could answer the questions: Is there feedback between technology and farm diversification? Is unidirectional causality hiding behind the false wall of a feedback mechanism because of limited data? One could argue that theory supports feedback between the two variables. For example, the technology of hybrid corn increased yields substantially. This cut the harvesting cost per bushel of corn because it cost the same to run the mechanical corn picker whether yields were 10 bushels per acre or 100 bushels per acre. Thus, hybrid corn technology spurred specialization, which in turn spurred the demand for technology in the form of mechanization. Very simply, feedback exists. Similarly, one could argue that corn- and soybean-specific herbicides, biotechnologies, fertilizers, etc. are encouraging production of only those crops in Iowa. Or, one could rebut that with the argument that the production of only those two crops is the cause behind the innovations because researchers know there will be a demand for the enterprise-specific technology applications. Again, feedback is present.

At any rate, one must start somewhere with what data is available. The Granger test is an excellent place to start. The main points in its favor are its simplicity in definition and testability in real-world application. It is hard to ask for more than that from an empirical test.

CHAPTER 6. CONCLUSION

Recommendations for Future Research

This thesis hypothesizes that specialization of Iowa agriculture at the farm level is the result of technological innovation, agronomics, and transactions costs. The evidence is mixed, but the topic will (hopefully) be researched more extensively in the future. One possibility for future research is to calculate the indices for other Iowa counties and for counties of other states. The data is not conducive to easy collection and organization. The process is quite tedious and time consuming. However, data for a large number of counties would likely reveal patterns useful in unraveling the threads of causation.

Another possibility lies in historical research. The data would be useful in a county historical context. An attempt could be made to match specific events along a county's timeline with the pattern of agricultural diversification shown on the index charts.

It would be interesting (and challenging) to empirically relate transactions costs to diversification. Transactions costs are difficult to measure, but not impossible. Allen and Lueck (1992, 1995, 1999, 2000) have successfully used a risk-neutral, transactions cost approach to explain the nature of agricultural contracts. Their theory is empirically supported. Similar research into farm diversification would be welcomed.

The specialization trend clearly starts in the 1930's for most of the counties. There are certainly alternative explanations for this. Federally subsidized crop insurance, as well as government price supports, began during that time. It is possible this had a direct impact on diversification. Clarke's (1994) hypothesis says government farm programs encouraged farmers to adopt new mechanical technology by taking uncertainty out of commodity prices. This would mean that government farm programs indirectly affected diversification. There are avenues for econometric research in this area.

Finally, the measures themselves could use more work. Pope and Prescott (1980, p. 555) summarize the issue as follows: "A great deal of research on diversification has been directed toward single-valued measures. However, when a vector of information is collapsed into a scalar, problems can arise." Each situation requires an appropriate measure of diversification. Perhaps the robustness of entropy and the HHI can be researched, and alternative empirical measures constructed.

One possible method of testing index robustness is through statistical inference tests. Each measure of diversification through time can be represented by a Lorenz curve. By imposing inequality restrictions, inference tests can be used to determine the ordering of the Lorenz curves. Hypotheses would be constructed to test for stochastic orderings, equality of the curves, or dominance in certain curves. For example, a null hypothesis could state that all Lorenz curves of Iowa farm diversification throughout the 20th Century are equal, or no change in diversification. The inference test would reject or fail to reject the null. Theoretical and empirical work on these tests has been done by Dardononi and Forcina (1998, 1999). Zheng and Cushing (2001) have extended the inference methods to test inequality indices with dependent and partially dependent samples. This would be important in testing diversification in Iowa agriculture because there is overlap in consecutive sampling years. A producer will be included in samples across years if he stays in agriculture, resulting in matched pairs. This gives partially dependent samples.

General Discussion

Technology's impact on Iowa agriculture is undeniable. It is not unusual to see a combine with a 30 foot flex header lumbering across a field at harvest time, all the while unloading into a 1000 bushel grain cart pulled by a 200 plus horsepower MFWD tractor. The pros and cons of such capital-intensive agriculture will be endlessly debated, as they should be, because the effects are far-reaching.

What lies in the future? Following the thrust of ideas presented in this thesis, two things will change farm level diversification. They are technology and agronomics. It is not hard to imagine the independent farmer of the future as purely a cash grain producer. Livestock is inexorably marching toward industrialization. Cow-calf operations, which are more subject to seasonality and less amenable to factory production, are somewhat common. But even their numbers are dwindling. It is possible a producer could raise livestock during the "growout period" on contract from an industrialized corporate farm. Even though such contract agriculture would likely carry a consistent profit, two things speak against it becoming prevalent. First, profit for the farmer would be slight and subject to strict contract specifications. Market power lies squarely with the corporate farm. This leads to the second point. Midwestern farmers are fiercely independent by nature. Most of them would not want to be told how to farm by invasive contract agreements. Also, they would prefer to get their profit from "the market", not contracts with corporates.

As technology continues to progress, not every family farm will be able to keep up with the threshold size. "Capital is the key input for today's and tomorrow's farming" (Butcher and Whittlesey, 1966, p. 1517). Many will continue to be supported by off-farm income. This is viewed by some as a temporary life raft, or a transition phase as smaller farms exit the market (Shucksmith *et al* 1989). Others see part-time farming as a stable, long-term condition (Olfert, 1992). Given that the doom of the family farm has been incorrectly prophesied for many years, it seem it has remarkable staying power. Yet, technology has the potential to change even that.

Organizational innovations that overcome transactions costs for very large farm sizes have been limited up to this point (Schmitt, 1991). They are perhaps not permanently limited. In their prescient article, Butcher and Whittlesey (1966, p.1518) state, "In recent developments, another goal has been to substitute mechanical for human sensing and controlling activities. In the newer 'automated processes', machines perceive, choose, and manipulate." The farmer can program the VR applicator and keep track of its progress with GPS. Really, all the hired man has to do is drive the tractor to the field and turn it around at the end of the row (the tractor steers itself down the row). As a matter of fact, even the driver could become obsolete. John Deere has begun research on a tractor that is completely independent of a driver. It would only need to be programmed with instructions for a certain field. Imagine the future if this becomes reality. A farmer is no longer an owner-operator-manager. A farmer is an owner-manager. Or, perhaps a farmer is an owner (with several hired managers). In any case, the workforce is now comprised of an army of fully automated machines that plant, apply chemicals, and harvest. They can detect and adjust to any field condition. Computer programs assimilate any number of variables to determine precisely when and where an activity will be performed. Each farm now operates tens of thousands of acres, maybe hundreds of thousands. This is many decades away from happening, if ever. The point is that it is within the realm of the possible, not only that of science fiction.

The previous applies more to farm structure. Whether organized by part-time farms, large full-time farms, or automated mega-farms, the future crop rotation is in question. Agronomics change over time. Diversification has much to do with biodiversity and agricultural sustainability (Gertler, 1996; Zandstra, 1992). There are indications that the corn-soybean rotation is coming under attack from diseases and pests that will be difficult to control. In this case, there might be limits to technology's abilities. And lest we not forget, South America possesses considerable comparative advantage in soybean production. It is not inconceivable that Iowa's future crop rotation will become more diverse in order to make agriculture sustainable. A group of researchers at ISU (including this author) are investigating the feasibility of introducing triticale as a third crop in the rotation. Results will be slow in coming, but current research signals possible changes ahead. Whatever lies ahead, it is a safe bet that technology will be at the forefront, continually pushing against the boundaries of agriculture.

APPENDIX A. DATA FOR INDICES

The data used in calculating the diversity indices were collected primarily from the Census of Agriculture, which was conducted by the United States Bureau of the Census until 1997, when it was taken over by the USDA. The Census is sent to all places of agricultural production, or any place defined as a farm. Farm definition has changed several times since the Census was first conducted. Potential candidates are first screened to ensure that a form is sent to only those who fit the farm definition. In recent years, statistical software packages have imputed values for nonresponse items on the forms received from producers. If there is complete nonresponse (the form is not mailed back), extensive follow-up is conducted. If it becomes impossible to obtain a response, the missing values are weighted and imputed. The standard errors of the estimates for all categories are listed in the past several Censuses. It is estimated that the last five have captured an average of 92 percent of farms and 98 percent of agricultural production. The sample obtained by the Census is assumed to be representative of the population. Consult the appendices of Census publications for complete statistical details.

It was impossible to find all necessary data solely from the Census. The 26 categories of enterprises were not all reported in each Census because the survey has changed over time. Furthermore, the definitions and categorizations themselves have changed, often from one Census to the next. See the individual Census publications for details.

It became necessary to employ a certain methodology to ensure as much consistency as possible in collecting data. It went as follows:

I. Since gross receipts, or value of production, were earmarked as the enterprise measure, the actual value of production for each enterprise and county, as given in the Census was used. It was usually calculated as quantity produced multiplied by the quantity-weighted county-average price. See the Census publications for complete details. If value of production was not reported, the data search moved to the second step.

II. At this point, it was necessary to find quantity and price data to compute value of production. This step entailed the gathering of production data at the county level for each enterprise from each Census. Consistency was quite good, as all production data was obtained from the Census.

III. Step three was to collect price data. This was more difficult. It went as follows.

  A. Again, the Census was searched first. They do not give county-level prices, only state-level. If a state-level price for an enterprise was listed, it was used.

  B. If prices were not listed, then a state-average price for the enterprise was calculated by dividing total production into total value of production, both being state figures.

  C. If steps A or B failed to produce price data, extraneous sources were sought. This was necessary in a few instances. There were three non-Census sources employed: a series of crop bulletins, a crop report publication, and yearly national agricultural statistics publications. All are USDA publications. Full source information is given in the "References" section. The raw data from which the indices were calculated are given in the tables of this appendix. Footnotes pinpoint which values were computed using non-Census price data.

The process can be summarized as:

1) value of enterprise production was used, if given, otherwise
2) it was calculated by multiplying enterprise quantity (county-level) by enterprise price (state-level), where
   a) quantity is taken from the Census
   b) price is taken either from the Census or from another USDA source

The major sources of inconsistency in the data arise from the changing definitions and categorizations used in the Census from year to year. There is perhaps a legitimate concern about values calculated with state-level prices (collected from different sources). However, any difference would not likely have a great effect on a measurement of a distribution comprised of 26 categories.

The tables below give the value of production data for all categories and all counties. All production data used in calculating the values are taken from the USDA's Census of Agriculture, except 1885 and 1925, when data was collected by the Census of Iowa. Price data used to calculate values is taken from the same USDA and Iowa Censuses, with the exception of those footnoted, which are taken from the three additional sources listed above in III.C. The footnotes are given only in Table A.1, Carroll County, but they apply to all counties (Tables A.2 through A.9) in exactly the same manner.

TABLE A.1 Carroll County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	743231[1]	866407[1]	1209720	1938811	7071002	3112946	3663534	1858529	3304762	8055028	7828476
Corn (harvesed for silage)	0	0	0	0	58213	36069	51066	0	61438	0	164873
Wheat	339622[2]	42257[2]	229095	74863	289090	30274	46304	23709	26478	7648	42796
Oats	159155[3]	278662[3]	453772	557904	1952973	1196923	995250	450090	465613	1002861	1918648
Barley	79028[4]	121454[4]	35460	56996	38662	30247	11955	56353	66465	0	1955
Rye	7491[5]	1822[5]	1226	119	2984	280	1758	2800	1714	396	20
Flax	0	27063	2617	104	323	0	0	1519	6726	10100	17126
Buckwheat	711[6]	1189[6]	650	459	0	0	0	0	0	0	0
Sorghums	0	0	0	0	0	0	490	29419	13111	6438	1753
Soybeans	0	0	0	0	0	1781	976	1203	9261	712768	649190
Potatoes and Sweet Potatoes	19407[7]	39949[7]	53241	98519	18173	50869	148708	62104	51572	35380	17157
Popcorn	0	0	0	0	0	18785	13282	0	28969	0	16278
Field Seeds	0	0	0	0	0	9631	10598	0	10983	13615	32944
Alfalfa	0	0	0	1910	22022	0	175275	311029	207386	354877	435082
All Other Hay	167740[8]	268088[8]	337177	553924	1003999	367053	332660	189834	112066	521065	432786
Vegetables	1020	1413	20748	125346	329454	8731	114697	17011	63308	142836	410
Value of Fruits and Nuts	7562	1413	16397	33516	35495	4916	35336	12142	10622	12119	2228
Horses and Colts	645631[9]	973894[9]	787546	1775735	1412649	954214	993790	844060	604955	360962	94546
Mules, Donkeys, Burros	32897[9]	45628[9]	33237	65099	87786	89554	88567	75454	55480	19536	4182
Cattle	497224[9]	1001112[9]	1164206	1114499	2582601	1864080	2811731	1109989	2363922	4783802	6843909
Swine	388376[9]	859631[9]	527733	802408	2003012	1583473	1666133	539448	505156	2472405	2839818
Sheep, Lambs, Wool shorn	1790[9]	2348[9]	17112[10]	25843	76563	57976	96029	59575	69198	136419	94850
Goats and Kids	0	0	478	89	106	210	252	96	45	63	19981
Poultry and Poultry Products	28958	90939	258657[10]	319515	679157	713340	1065463	506849	554005	1686566	1524539
Bees and Honey Produced	245	0	4129	5968	6700	1453	4458	0	3385	0	7550
Dairy Products	76263	171511	266759	287739	404454	483114	669522	742188	404656	774604	878287

TABLE A.1 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	9129064	9459549	11875323	13015076	33811191	32599694	37603940	27687594	46903372[15]	45812842[17]
Corn (harvested for silage)	220082	306385	811359	1304752	4359474	0	5895004	823834	0	0
Wheat	2279	6720	2170	1895	197	22040	13177	56041	0[15]	16306[17]
Oats	2136508	1621164	1054786	590281	1389505	985135[11]	1266041[12]	790167	564310[15]	303464[17]
Barley	5019	15472	3310	255	0	0[11]	0[12]	0	0[15]	0[17]
Rye	137	44	562	606	0	0[11]	0[12]	0	0[15]	0[17]
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	48209	82715	150470	58199	32780	251233	33832	0	0[15]	0[17]
Soybeans	1470132	1092942	3929987	4065044	15338508	22424149	21347695	26425990	30534641[15]	39476874[17]
Potatoes and Sweet Potatoes	10275	2180	11829	8737	0	0	165	0	0[15]	0[17]
Popcorn	51024	4665	58566	0	43908	0	7873740[13]	0	0	0
Field Seeds	15737	86952	2564	548	1097	0	0	0	0	0
Alfalfa	509460	732207	1032340	916495	1451438	2194025	2555436	201005	215514[15]	312840[18]
All Other Hay	637051	358737	510582	1153519	405577	197197	89676	1604435	3129984[15]	2873970[18]
Vegetables	4023	1950	1175	5933	0	0	0	0	0	0
Value of Fruits and Nuts	3478	8139	7932	9447	1000	0	0	0[14]	636[15]	5377[17]
Horses and Colts	47253	69443	6886	58428	27061	74549	152397	41500	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	7234511	12253926	13708188	23208759	17061908	53630874	50734751	45960858	44834730[15]	41778720[18]
Swine	5110614	3678384	5098486	9022167	10225049	23227581	24491407	21768479	24773250[15]	31670830[17]
Sheep, Lambs, Wool shorn	166397	193359	179804	119952	56000	105000	325951	534632[14]	201264[16]	537057[19]
Goats and Kids	0	0	5	0	0	0	0	0	0	0
Poultry and Poultry Products	1082072	1010660	1631811	954479	928000	200000	61000	95000	100000	9000
Bees and Honey Produced	0	0	0	0	0	0	0	0	0	0
Dairy Products	928695	1412410	1427562	1119988	985000	1031000	0	646000	563000	406000

Price data footnotes for Table A.1

[1] from "Corn Crops of the United States, 1866-1906"
[2] from "Wheat Crops of the United States, 1866-1906"
[3] from "Oat Crops of the United States, 1866-1906"
[4] from "Barley Crops of the United States, 1866-1906"
[5] from "Rye Crops of the United States, 1866-1906"
[6] from "Buckwheat Crops of the United States, 1866-1906"
[7] from "Potato Crops of the United States, 1866-1906"
[8] from "Hay Crops of the United States, 1866-1906"
[9] from "Number and Farm Value of Farm Animals In The United States, 1867-1907"
[10] from *Crop Reporter,* Vol. 1
[11] from "Agricultural Statistics", 1979
[12] from "Agricultural Statistics", 1984
[13] from "Agricultural Statistics", 1982
[14] from "Agricultural Statistics", 1989
[15] from "Agricultural Statistics", 1994
[16] sheep price from "Agricultural Statistics", 1993; wool price from "Agricultural Statistics", 1994
[17] from "Agricultural Statistics", 1999
[18] from "Agricultural Statistics", 1998
[19] sheep price from "Agricultural Statistics", 1999; wool price from "Agricultural Statistics", 1998

TABLE A.2 Decatur County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	335326	418992	565685	612852	2699596	1458508	1232640	68598	795781	2132211	2975030
Corn (harvesed for silage)	0	0	0	0	260498	8676	6042	0	3824	0	5594
Wheat	4706	8125	4175	41738	902618	47468	80895	2744	11312	13152	98445
Oats	91644	116370	98754	161613	459219	285469	237188	752	132732	231105	533287
Barley	23	298	510	231	1060	238	3626	0	0	0	250
Rye	4144	2386	2944	1383	12873	3763	2077	808	1243	409	2218
Flax	0	557	127	0	0	0	0	764	0	0	21
Buckwheat	2193	605	1019	200	588	920	11	0	0	0	20
Sorghums	0	0	0	0	0	0	434	11547	22082	10293	18946
Soybeans	0	0	0	0	0	6996	24792	37383	13309	112056	155396
Potatoes and Sweet Potatoes	19620	16374	14374	11873	3227	20799	27692	5979	13937	6274	18589
Popcorn	0	0	0	0	0	694	86	0	3867	0	4536
Field Seeds	0	0	0	0	0	109312	77124	0	52039	157379	153564
Alfalfa	0	0	0	102	5786	0	91437	23362	67937	177376	240486
All Other Hay	220088	348377	307296	447333	680849	301794	353799	271292	143994	497422	431082
Vegetables	3347	1320	42264	57039	140346	26996	96324	7294	81391	139419	247
Value of Fruits and Nuts	31431	1320	27748	113803	55045	28505	38829	4233	12450	12175	8299
Horses and Colts	582354	1015941	773091	1646801	938283	587475	509964	544115	410490	276600	148092
Mules, Donkeys, Burros	35653	31110	39252	117614	139180	109267	95822	67071	37899	29064	5346
Cattle	610714	1050314	989258	906318	1803901	1159754	1840179	632492	1391803	2483958	4192216
Swine	181358	437145	265660	339074	777777	565553	610763	179135	188506	832796	1125629
Sheep, Lambs, Wool shorn	63595	23824	80458	90143	226307	164988	195311	93549	152879	154343	348329
Goats and Kids	0	0	1769	577	46	222	136	184	187	303	500
Poultry and Poultry Products	73796	94016	256467	327026	712226	552975	741835	271672	290253	847279	617832
Bees and Honey Produced	1707	0	6285	8473	12817	9722	6031	0	2102	0	363
Dairy Products	62730	96897	131063	146791	255921	306263	473858	466907	220214	489915	609025

TABLE A.2 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	2008269	1881186	2432784	2444749	6017217	8724668	8870458	5529879	6765838	6507755
Corn (harvested for silage)	172074	63701	106395	205680	1301438	1357380	1191329	323878	0	0
Wheat	25531	38159	17762	13683	29194	12581	183365	18769	0	22543
Oats	553037	150052	179710	131682	312689	91292	77066	57890	34334	65638
Barley	3789	119	588	0	0	0	0	0	0	0
Rye	2412	1317	551	291	0	0	0	0	0	0
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	21528	50418	36576	38499	25563	0	32797	0	0	0
Soybeans	845458	509122	1426119	1214721	3146062	7181797	6053479	5942234	4039247	7918722
Potatoes and Sweet Potatoes	4275	775	2415	3297	74	0	0	0	873	0
Popcorn	625	16	1247	0	0	0	3407040	0	0	0
Field Seeds	53762	64761	11251	219	15203	0	0	0	0	0
Alfalfa	371180	708891	889519	870456	1365132	2352046	3814521	1876021	4478916	4526940
All Other Hay	395552	231251	466826	342300	1237770	1096035	1257379	1012507	1588938	4018520
Vegetables	975	185	906	1	0	0	0	0	0	0
Value of Fruits and Nuts	3208	2526	2856	11424	2000	0	0	55297	0	0
Horses and Colts	89490	94267	3619	81589	79701	112948	293094	399500	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	3838073	5687526	6248223	10174395	11212912	26643260	28362279	28241497	29380395	35125110
Swine	1739957	1278279	1421524	2045170	1646213	4506147	4403211	3506051	3178200	3318145
Sheep, Lambs, Wool shorn	181260	194754	161094	135731	71000	71000	158251	350611	218960	598226
Goats and Kids	0	0	0	0	0	0	0	0	0	0
Poultry and Poultry Products	524428	428901	346705	76225	15000	10000	17000	9000	22000	15000
Bees and Honey Produced	0	0	20	0	0	0	4000	0	0	0
Dairy Products	567580	522571	743820	568780	740000	509000	627000	771000	515000	459000

TABLE A.3 Fayette County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	472615	513609	907903	1505020	4427351	1052587	1908664	2546630	2371722	5198025	6964908
Corn (harvesed for silage)	0	0	0	0	488118	252207	431644	0	306549	0	628188
Wheat	38894	11638	29540	16926	92743	15275	10668	4022	2269	1302	6864
Oats	368463	425510	556590	668256	1945691	1369922	895974	307042	635865	1444892	2399244
Barley	12640	11439	68679	130222	173840	31057	89254	17656	11812	1340	928
Rye	3965	3626	4637	5060	10421	6641	6377	1638	3912	1580	4526
Flax	0	10991	24206	2932	348	216	2989	246	2738	0	637
Buckwheat	3414	7125	7241	7480	12886	3922	6256	0	541	0	0
Sorghums	0	0	0	0	0	0	0	14367	26924	1440	1099
Soybeans	0	0	0	0	0	11445	20304	46217	76725	837967	455976
Potatoes and Sweet Potatoes	53957	47024	55409	79573	0	73556	113118	93652	52080	31057	22785
Popcorn	0	0	0	0	0	772	635	0	432	0	5918
Field Seeds	0	0	0	0	0	39093	26221	0	34097	48500	270682
Alfalfa	0	0	13	357	550	0	26980	105016	83984	118064	416842
All Other Hay	425296	523989	387122	911343	1985574	656741	858756	646486	456451	1216430	1142460
Vegetables	9048	2531	42225	158588	419712	23371	131663	54416	106243	274427	28435
Value of Fruits and Nuts	27318	2531	25442	39048	69016	17797	51983	4233	22496	21716	6629
Horses and Colts	949548	1261342	1000408	2208335	1547120	1054200	1099250	1060385	845305	564762	199233
Mules, Donkeys, Burros	12773	15728	13115	32970	40435	33165	36079	28468	19756	10032	4180
Cattle	932334	1498926	1326038	1833014	3705352	2770275	3727669	1297756	3094911	5704921	8991977
Swine	346970	596738	537725	793902	1731790	1021918	1289528	442365	576350	2439607	2973742
Sheep, Lambs, Wool shorn	13174	11164	71171	77687	42389	111908	181977	88215	84690	74467	134263
Goats and Kids	0	0	492	125	551	288	868	371	88	320	13527
Poultry and Poultry Products	50298	125765	336275	485537	1199450	1063253	1491224	720103	847582	2542193	2353446
Bees and Honey Produced	12670	0	5155	14857	25802	6200	11571	0	4908	0	2200
Dairy Products	395496	509435	623373	919417	1630746	1872770	2181100	2034891	1257163	2929483	3631918

TABLE A.3 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	10253334	8880916	7608519	10811066	39114033	39958993	46905318	33192959	49937436	54324320
Corn (harvesed for silage)	589229	549150	1369104	1076608	3328595	0	4136236	19447193	0	0
Wheat	7860	1435	10524	7554	43642	13967	31426	16607	2989	9448
Oats	1937776	1593781	1274314	837138	2170866	1189608	1499607	1547237	913063	684993
Barley	17190	23364	6010	1717	7510	8151	8436	38027	44329	59174
Rye	49	1411	3154	1734	0	0	0	0	0	0
Flax	0	29	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	7603	13927	15674	7413	32600	36408	0	0	0	0
Soybeans	866984	884315	2125576	2654163	12590883	17153609	12962619	16192928	16674890	31229910
Potatoes and Sweet Potatoes	6984	4218	6630	755	61	301	0	0	0	0
Popcorn	594	117	46	0	0	0	0	0	0	0
Field Seeds	65223	15795	4915	2821	2093	0	0	0	0	0
Alfalfa	1011480	1348457	1720986	1623652	4181013	5986658	6516734	5672022	7362654	9200180
All Other Hay	1014847	563252	92472	489058	1006882	306397	523499	236252	646074	972510
Vegetables	37352	55570	69266	82081	176000	271000	0	80000	0	114000
Value of Fruits and Nuts	3465	7453	2817	4753	0	2000	0	0	8537	47225
Horses and Colts	79629	93839	14508	77300	97472	104098	234895	317500	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	7911088	11866141	11746589	17527842	16093871	41092294	37650326	42719618	43112730	33782760
Swine	6154678	4146253	4372976	7367496	7413051	18250306	20750044	16045505	17817450	17374085
Sheep, Lambs, Wool shorn	124686	162136	107331	96355	99000	151000	313201	928615	723274	976422
Goats and Kids	0	0	70	0	0	0	0	0	0	0
Poultry and Poultry Products	1648524	1565315	1769930	1672632	2171000	2341000	2602000	1589000	1557000	542
Bees and Honey Produced	0	0	174	0	0	2000	5000	45000	0	0
Dairy Products	4176473	6064100	8234469	9175177	15670000	18165000	25345000	25100000	26729000	25105000

TABLE A.4 Hancock County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	95148	199244	701570	1309873	4476542	2098596	2706787	2673702	2899819	5853874	7393604
Corn (harvesed for silage)	0	0	0	0	191924	141411	225319	0	174530	0	403791
Wheat	79310	42727	130275	23860	69706	11500	5716	1343	1376	525	6678
Oats	113362	200550	610350	596668	2154559	2018438	1312626	693139	1008725	1670931	2065888
Barley	27202	28976	72363	38695	51170	43479	164476	35506	16814	28	4030
Rye	1876	1055	3764	2250	2942	15597	18581	4695	3972	978	1527
Flax	0	22649	46619	2720	9335	1014	4982	979	18179	5098	36064
Buckwheat	1565	2427	381	1083	3908	385	489	0	0	0	0
Sorghums	0	0	0	0	0	0	1775	40915	26475	8217	2792
Soybeans	0	0	0	0	0	2959	1626	10432	105286	1383528	1502852
Potatoes and Sweet Potatoes	15248	19350	22699	62574	15050	61663	231933	234473	169672	25405	116661
Popcorn	0	0	0	0	0	123	195	0	316	0	3728
Field Seeds	0	0	0	0	0	2973	3297	0	10184	8619	29485
Alfalfa	0	0	0	569	5104	0	132058	255136	141401	321557	362880
All Other Hay	122905	277079	256099	498826	982597	308052	295522	365616	194162	376678	382266
Vegetables	2315	598	7879	75798	270706	26212	138267	29055	86731	171918	138954
Value of Fruits and Nuts	1215	598	4364	17370	43310	15726	28915	4233	8820	16216	1411
Horses and Colts	199840	430872	617211	1384671	1241076	897890	971140	861537	572161	312060	93906
Mules, Donkeys, Burros	6157	10024	12654	28353	41154	49442	48890	42380	18778	8880	2450
Cattle	193830	539304	891548	889148	2154860	1513331	2329290	1026746	2088938	3482410	5337181
Swine	69255	234513	272294	451731	1509756	1066519	1253286	443117	463188	2296561	2381131
Sheep, Lambs, Wool shorn	2972	1580	18662	28971	56651	31898	79752	96510	81468	95080	117605
Goats and Kids	0	0	269	150	52	60	106	118	29	88	803
Poultry and Poultry Products	6988	73664	197627	248832	579146	684930	940796	493096	662049	2011657	1859532
Bees and Honey Produced	235	0	1559	4285	13061	2085	6208	0	7091	0	5451
Dairy Products	32519	112031	191543	345430	633207	814316	1103856	1086314	603561	1096342	1200802

TABLE A.4 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	10448796	10143054	12055518	13189747	38142869	38361743	45384160	27277307	48869726	53095434
Corn (harvesed for silage)	405331	468852	682746	553344	1725738	1791213	1598172	311284	0	0
Wheat	929	9413	3602	15548	14033	17544	6373	0	4331	0
Oats	1502963	1635783	865732	539334	1198564	613830	580816	363092	238821	100763
Barley	635	3792	2520	4386	0	13680	0	0	0	0
Rye	480	647	130	0	0	0	0	0	0	0
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	4858	31165	23214	390	12441	29604	0	0	0	0
Soybeans	2475456	2259602	5355417	6608178	22476287	27456935	25072438	26432506	25407387	35768982
Potatoes and Sweet Potatoes	34931	6974	24656	12720	0	0	0	0	0	0
Popcorn	19924	4512	1180	0	0	0	0	0	0	0
Field Seeds	2729	135	864	0	0	0	0	0	0	0
Alfalfa	667040	990336	10263365	634737	1044534	1333173	1239411	775420	895986	606650
All Other Hay	409932	138601	195572	124305	186505	107755	79013	119908	140556	416460
Vegetables	28400	2630	2787	2530	0	0	0	0	0	6000
Value of Fruits and Nuts	223	1529	706	7641	0	0	0	0	0	0
Horses and Colts	0	66340	7931	42606	53717	85949	118198	180000	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	5320567	7806304	6929666	8995101	5986331	16555506	12367593	9895434	9884895	6621120
Swine	5269319	2964261	3795106	6505548	6396069	15493974	17036925	12079129	12498150	14842785
Sheep, Lambs, Wool shorn	166526	257823	241671	263809	147000	269000	532002	475686	337815	449221
Goats and Kids	0	0	42	0	0	0	0	0	0	0
Poultry and Poultry Products	1588397	2077186	2706046	1023338	540000	393000	1082000	5241	525	1370
Bees and Honey Produced	0	0	0	0	0	0	0	0	0	0
Dairy Products	996672	1436245	1782722	1417293	1457000	1760000	2466000	595000	805000	1740000

TABLE A.5 Jasper County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	849918	1096892	1702583	2745629	7546742	3612352	3825407	533144	3889621	6308714	9260534
Corn (harvesed for silage)	0	0	0	0	334938	79230	50556	0	46640	0	98466
Wheat	147839	42036	162390	122151	630222	206446	157404	38648	60384	14899	304725
Oats	316623	419650	450022	534081	1431986	1131426	966172	91067	546133	919999	1761776
Barley	3264	5092	9681	18540	11110	4113	35578	884	6587	0	3155
Rye	11821	6563	2025	2667	11607	3619	3215	1436	3482	2222	2549
Flax	0	2173	49	134	0	0	0	487	902	0	0
Buckwheat	862	469	84	210	719	0	188	0	0	0	100
Sorghums	0	0	0	0	0	0	0	15132	40676	5338	11815
Soybeans	0	0	0	0	0	5072	8931	10124	117656	987142	681969
Potatoes and Sweet Potatoes	117568	181682	122518	65064	6219	38767	71975	18605	25882	13044	13452
Popcorn	0	0	0	0	0	339	513	0	515	0	1512
Field Seeds	0	0	0	0	0	69652	83928	0	86526	27788	55820
Alfalfa	0	0	0	467	14300	0	172997	194537	183606	383878	960477
All Other Hay	276457	393399	276220	663169	900386	466627	630697	172048	341120	877649	332040
Vegetables	7507	5425	53011	154427	202411	23531	174794	6654	117092	179888	3873
Value of Fruits and Nuts	68992	5425	48859	72885	71278	27425	64539	23148	33198	21030	15301
Horses and Colts	1039769	1594502	1231688	2815330	1762298	1291982	1075354	949589	726555	381752	139650
Mules, Donkeys, Burros	63496	61874	71715	148830	162517	139127	109042	87892	55411	25359	6496
Cattle	1121354	1603202	1588022	1771365	3742723	2364667	2972088	1099118	2920260	5054029	8269918
Swine	577377	1271013	737972	1249852	2958387	2492569	2146846	623391	812307	3126411	3994694
Sheep, Lambs, Wool shorn	11887	21586	124091	75986	288535	269213	240025	94657	127140	155193	249056
Goats and Kids	0	0	4656	2761	346	900	400	226	146	81	329
Poultry and Poultry Products	49442	153960	378597	518371	1038729	1049171	1334006	577091	740990	2008365	1626833
Bees and Honey Produced	5440	0	5391	11230	24098	6902	16928	0	4669	0	389
Dairy Products	197372	244708	292043	279838	510098	610892	1002212	973129	552939	1122105	1668449

TABLE A.5 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	10862369	9837178	12929877	14418177	35796562	37523843	47372330	30100460	49127274	50365250
Corn (harvesed for silage)	122664	179796	386988	632168	2124817	1781388	1839877	461224	0	0
Wheat	26315	48088	22511	3289	48828	7480	23021	6134	17995	0
Oats	1956143	1477834	1055106	762099	1388033	988991	1172770	764538	618179	395694
Barley	2146	221	0	612	5826	0	0	0	0	0
Rye	2518	686	416	194	0	0	1058	0	0	0
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	7149	35478	17518	26848	15267	35632	0	0	0	0
Soybeans	1368746	1058099	3007239	4726616	13068448	18497551	21004928	24285969	25743538	42700547
Potatoes and Sweet Potatoes	6151	1754	7320	4561	37	0	0	0	0	0
Popcorn	3570	1265	9	0	0	0	0	0	0	0
Field Seeds	37241	31807	30170	2809	2145	0	0	0	0	0
Alfalfa	1171460	1297402	1311709	1306473	2270347	3564206	4722740	2824768	5052138	6621340
All Other Hay	843257	464012	638309	386277	754507	326962	246048	170643	610350	806850
Vegetables	0	5818	4179	370	0	0	5000	0	0	0
Value of Fruits and Nuts	8488	27160	7386	10014	7000	45000	0	0	0	0
Horses and Colts	66405	109033	12079	104751	74316	116998	275395	439000	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	7975469	11934832	11718543	17891517	15802726	35603813	34174294	32293730	33396960	26229120
Swine	7210332	4820918	5696323	8803822	9271244	20159162	21812000	16392711	17494050	15363155
Sheep, Lambs, Wool shorn	353650	486866	273868	199510	161000	327000	542302	940822	517698	596316
Goats and Kids	0	0	0	0	0	0	0	0	0	0
Poultry and Poultry Products	1141760	971796	1050224	512767	588000	548000	615000	648000	161000	143000
Bees and Honey Produced	0	0	1144	0	0	0	0	6000	0	28000
Dairy Products	1591728	1859838	2372789	2244154	2501000	3315000	4028000	1909000	2713000	1468000

TABLE A.6 Linn County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	740611	760096	1220228	2415203	5990738	1738028	2682655	2435938	3404688	6930806	8414460
Corn (harvesed for silage)	0	0	0	0	368162	154304	213830	0	146086	0	243139
Wheat	23011	5729	15410	35109	150602	22618	25640	5203	5785	4645	35289
Oats	288762	326589	466460	790441	1657787	1468326	896307	202247	590350	1234438	1891084
Barley	961	2363	18003	49396	49332	24264	52361	6815	15745	341	6580
Rye	8291	6417	7741	10468	32061	7557	7538	1291	4148	1821	2887
Flax	0	705	382	9	258	0	1720	43	3738	0	1440
Buckwheat	1970	2009	2475	1020	2292	742	2289	0	63	0	0
Sorghums	0	0	0	0	0	0	4257	25285	19735	1880	577
Soybeans	0	0	0	0	0	9803	21482	61508	189573	955863	504074
Potatoes and Sweet Potatoes	49148	50265	61669	110918	15363	79959	169400	103003	64819	35819	47904
Popcorn	0	0	0	0	0	27173	5294	0	2182	0	12982
Field Seeds	0	0	0	0	0	21601	46450	0	35227	37392	136369
Alfalfa	0	0	0	679	9438	0	62323	216430	141712	220900	618150
All Other Hay	472676	584622	351390	851833	1699163	571308	704584	741337	420504	851583	787120
Vegetables	11723	11319	70055	265257	483791	74854	309326	59523	190809	273229	74517
Value of Fruits and Nuts	45489	11319	46122	106299	237794	74272	97906	38664	69666	71675	65886
Horses and Colts	1179488	1537791	1120178	2369722	1667856	1134726	1050758	969072	713859	458320	142738
Mules, Donkeys, Burros	36756	41998	34015	57760	90648	81369	72434	64030	45145	29646	6656
Cattle	1290302	1577670	1379220	1662546	3979106	2214050	3178461	1248768	3161071	5476823	8021623
Swine	468164	914914	645315	840916	2135519	1356999	1515705	596687	837942	3260056	3658646
Sheep, Lambs, Wool shorn	8423	11641	53497	103970	151818	101143	119250	86455	69020	97969	237967
Goats and Kids	0	0	2427	165	260	1164	1444	435	202	660	2462
Poultry and Poultry Products	74935	165266	393716	483164	1017518	1093237	1520149	637881	733599	1967209	1489309
Bees and Honey Produced	9224	0	5608	13590	28473	5037	26117	0	7127	0	2599
Dairy Products	464585	493647	522708	566871	814270	1011545	1438500	1383639	1183739	2062273	2561713

TABLE A.6 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	11186499	9607745	11423780	12143004	34203129	31907528	43333893	24364298	38676986	41554590
Corn (harvesed for silage)	376797	330141	693881	750176	1465578	0	1771097	668667	0	0
Wheat	16053	2091	7847	6813	93011	5893	77085	29709	19962	55815
Oats	1893132	1526432	1130933	711571	1285872	802675	797172	819889	553484	445795
Barley	13924	7782	2024	2465	0	0	1328	0	0	0
Rye	341	1489	972	582	0	0	4316	0	0	0
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	4760	20982	6913	11408	16525	22599	0	0	0	0
Soybeans	700734	585690	2261256	3363647	14500137	18907273	19324339	18504562	20802783	31323372
Potatoes and Sweet Potatoes	22300	7004	21996	2947	447	1484	6111	1349	8924	0
Popcorn	851	142	7163	0	22525	0	0	0	0	0
Field Seeds	26553	15930	12111	3752	2819	0	0	0	0	0
Alfalfa	1083660	1091154	1306769	719736	2006814	2976949	2961643	2674278	4115124	4923050
All Other Hay	727212	475598	530388	346558	855406	217210	333271	381153	483210	584760
Vegetables	66437	81346	41846	64523	132000	137000	131000	420000	377000	294000
Value of Fruits and Nuts	17748	44551	32202	48851	39000	0	105000	162013	73809	28848
Horses and Colts	80997	129149	20092	133822	151189	191997	462591	804000	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	7567562	11031995	9711766	11756953	10145218	21482425	22164308	25449229	26598750	20970300
Swine	7130980	4595455	4731383	6351618	6285809	13301850	12042062	10028627	9643050	6825585
Sheep, Lambs, Wool shorn	362868	430093	367824	235450	156000	261000	661952	1138296	522340	488190
Goats and Kids	0	0	52	0	0	0	0	0	0	0
Poultry and Poultry Products	1142639	1027156	986956	444420	498000	178000	127000	40000	32000	19000
Bees and Honey Produced	0	0	650	0	0	14000	25000	84000	25000	57000
Dairy Products	2488062	3161990	3018759	3009182	3712000	4587000	5891000	4976000	3886000	3753000

TABLE A.7 Louisa County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	390310	400826	723298	1361599	3326887	1571025	1597828	920872	1717448	3661142	4830862
Corn (harvesed for silage)	0	0	0	0	103454	66543	42183	0	22818	0	59089
Wheat	21084	25904	6410	261761	838937	283894	239979	102290	115501	57231	212557
Oats	117746	113527	178982	216569	516973	395056	271382	12194	6626	329452	711634
Barley	0	0	993	7807	3298	0	10068	222	2232	0	11300
Rye	7446	8235	8836	14866	76396	15490	11358	6949	7714	7039	19751
Flax	0	0	39	0	0	0	0	181	0	0	0
Buckwheat	1256	757	157	146	0	0	0	0	0	0	0
Sorghums	0	0	0	0	0	0	62	1619	14932	102	469
Soybeans	0	0	0	0	0	5207	12386	59410	183204	1046365	977561
Potatoes and Sweet Potatoes	28350	15131	19604	29970	4332	28726	62617	25031	21248	17150	22286
Popcorn	0	0	0	0	0	105	0	0	0	0	546
Field Seeds	0	0	0	0	0	14125	36713	0	27144	40786	51067
Alfalfa	0	0	0	340	4862	0	32705	36549	37892	103523	234209
All Other Hay	161125	200727	128689	297548	580407	211212	238766	311813	156394	392948	207282
Vegetables	4416	1115	67868	105033	243486	11449	123460	12565	81511	155662	31526
Value of Fruits and Nuts	29430	1115	35980	34044	47115	15455	41567	13861	17969	18890	12403
Horses and Colts	561107	772487	419362	1452573	989956	566785	468545	484996	291865	195610	50426
Mules, Donkeys, Burros	22789	14777	29532	47667	71259	47466	39703	40353	23522	11613	2040
Cattle	517660	703380	623377	783871	1723931	906594	1205681	526526	1291795	2334620	3280933
Swine	202571	421385	333365	621010	1505099	1007412	853007	348188	391768	1832778	2277914
Sheep, Lambs, Wool shorn	5971	5398	31270	36617	55370	48692	74848	43410	41028	67178	76737
Goats and Kids	0	0	612	1984	1057	720	41	47	29	105	100
Poultry and Poultry Products	29283	68025	171526	215262	457899	404890	501604	191428	197340	521796	332891
Bees and Honey Produced	4104	0	4039	8190	11808	2779	4856	0	1885	0	203
Dairy Products	77613	95865	114117	79104	212617	200701	388616	393456	155686	334037	371124

TABLE A.7 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	5998144	5428102	6614611	7613295	21601323	20385602	26764829	11470136	21605296	21933339
Corn (harvesed for silage)	92990	100800	140828	134904	383919	425851	406518	155880	0	0
Wheat	79408	63933	76047	34922	156849	42076	122718	65515	85037	40811
Oats	825840	542581	314280	200450	297000	136974	161547	87018	52400	78494
Barley	147	420	680	0	0	0	12266	0	0	0
Rye	8001	6447	5816	3683	0	3796	0	5001	10053	22725
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	1125	44441	6832	4482	0	0	0	0	0	0
Soybeans	1676520	1160656	2202092	3078934	8571335	11076234	10823712	9481135	13068489	18722425
Potatoes and Sweet Potatoes	23010	1625	10231	10648	296463	0	440206	374308	507858	0
Popcorn	1469	28	0	0	0	0	0	0	0	0
Field Seeds	25063	11575	17142	0	0	0	0	0	0	0
Alfalfa	526680	376928	407834	232959	441976	576847	682911	570498	1122108	1244870
All Other Hay	240815	145935	151767	91630	280616	94838	160691	75289	118404	183590
Vegetables	48823	101243	82032	81072	259000	370000	403	387000	43000	100000
Value of Fruits and Nuts	5947	19498	6235	0	0	0	0	98049	11325	4025
Horses and Colts	29982	55533	4991	63098	30696	44699	109798	133000	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	3494931	5136798	3977294	5215147	4196238	10181483	8205508	7314254	7044210	6423330
Swine	4108381	2801600	2889963	4154122	3552732	8077376	8065178	5202204	4495125	7666065
Sheep, Lambs, Wool shorn	134694	176052	132427	135873	86000	68000	185001	325673	112305	160411
Goats and Kids	0	0	70	0	0	0	0	0	0	0
Poultry and Poultry Products	259023	430936	385436	269497	66000	125000	129196	161214	305000	150
Bees and Honey Produced	0	0	20	0	0	14000	0	0	0	0
Dairy Products	323551	279075	231557	201694	52000	0	0	278000	0	146000

TABLE A.8 Mills County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	744763	751580	1160643	1848599	4438658	3026833	3650360	171955	1931608	5726277	5987478
Corn (harvesed for silage)	0	0	0	0	42412	7580	18299	0	28146	0	39675
Wheat	56517	39812	105535	151541	941204	221996	240670	148331	147360	166015	509722
Oats	59062	88865	102428	131516	325935	299494	233371	75245	54668	323790	476261
Barley	2375	5146	3024	8370	28470	7797	21095	3762	20525	0	4363
Rye	7140	1108	1759	601	16290	2896	2978	2583	2085	544	2278
Flax	0	0	0	0	0	280	0	17	0	4861	2100
Buckwheat	275	144	17	40	187	0	0	0	0	0	0
Sorghums	0	0	0	0	0	0	95	8942	27458	3864	4240
Soybeans	0	0	0	0	0	365	425	32	2787	68007	18150
Potatoes and Sweet Potatoes	22339	26977	41062	55063	6675	38339	86101	4733	36194	9346	19319
Popcorn	0	0	0	0	0	564	1045	0	5684	0	14470
Field Seeds	0	0	0	0	0	22588	25794	0	18274	10411	6570
Alfalfa	0	0	14077	86097	546018	0	431418	288858	153520	466035	538741
All Other Hay	102425	166473	196557	340219	368590	296252	143315	39049	41363	98138	135667
Vegetables	12581	4364	47356	95694	161069	14906	70538	1144	57407	115870	29640
Value of Fruits and Nuts	65283	4364	64720	223128	87949	10752	49290	34196	33973	7693	0
Horses and Colts	593285	928480	633564	1424993	855631	602240	548017	524465	332698	230736	71381
Mules, Donkeys, Burros	74431	75441	78139	171444	168531	140870	150871	119861	84158	33696	5382
Cattle	636662	810091	1016473	896998	1674188	1046949	1602369	572051	1199539	2204202	3937818
Swine	244992	623919	412618	661939	1435537	868984	927513	326033	260059	301916	1453010
Sheep, Lambs, Wool shorn	1674	1754	12562	23892	72727	28199	48633	16257	23483	134045	149038
Goats and Kids	0	0	410	381	144	606	120	127	133	228	62
Poultry and Poultry Products	25690	81124	188671	209725	407924	415468	556966	227709	209665	609667	364137
Bees and Honey Produced	1108	0	4522	2730	11852	6617	10156	0	9789	665681	191
Dairy Products	50442	89320	128198	114415	255720	221595	499141	428464	331258	532588	548238

TABLE A.8 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	4794579	6797515	6343017	8644603	14432959	20863524	20573433	15674852	29808920	26457399
Corn (harvesed for silage)	174718	123579	216249	391696	1615278	0	967468	92197	0	0
Wheat	402432	437059	291571	14690	485145	224802	274635	50877	29722	60650
Oats	826190	466979	114932	114848	249895	125734	587914	89266	78993	39767
Barley	6349	5285	1764	0	0	0	0	0	0	0
Rye	3549	3693	473	262	0	0	0	0	0	0
Flax	0	0	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	33458	271063	166944	35874	9235	34640	0	0	0	0
Soybeans	274841	334078	2589074	3751907	11885761	16430550	15772813	16011596	19892074	23808029
Potatoes and Sweet Potatoes	6543	3162	14931	1738	102	0	0	0	873	0
Popcorn	37062	11723	18550	0	21759	0	0	0	0	0
Field Seeds	72339	11435	2748	840	3048	0	0	0	0	0
Alfalfa	902720	568299	549359	454438	747022	986708	1068271	618197	1099644	1478950
All Other Hay	129121	57541	86617	48525	93459	96878	111215	89282	67782	223960
Vegetables	5974	12010	5777	310	0	10000	14000	0	0	0
Value of Fruits and Nuts	23680	23875	33231	51487	54000	202000	0	0	0	0
Horses and Colts	39045	49969	2944	44607	26522	49049	91198	129000	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	4245884	5788832	5953913	8340485	7084037	17511141	13468761	11759133	11063850	8079750
Swine	2913043	1885868	2102509	2722520	2217980	5646556	5384667	3375270	3003675	1491240
Sheep, Lambs, Wool shorn	91828	127338	73841	47408	32000	67000	145601	227552	117794	172581
Goats and Kids	0	0	0	0	0	0	0	0	0	0
Poultry and Poultry Products	215570	269996	118754	43004	15000	12000	5000	7000	396	7000
Bees and Honey Produced	0	0	0	0	0	0	0	0	0	0
Dairy Products	594263	516055	308711	216882	239000	252000	265000	117000	142000	137000

TABLE A.9 O'Brien County

	1885	1890	1900	1910	1920	1925	1930	1935	1940	1945	1950
Corn (harvested for grain)	171538	363926	965948	1832714	7203437	3024016	3475469	3099199	3668307	6589626	7293764
Corn (harvesed for silage)	0	0	0	0	171730	59228	55403	0	71044	0	231470
Wheat	67208	115665	243990	8444	56623	1308	2589	2016	3495	30	3872
Oats	96338	216576	345298	813178	2744454	1783063	1381948	723861	693660	1481894	2081763
Barley	44535	276416	302772	124685	133836	68901	382071	319980	348244	347	56083
Rye	3128	502	312	0	1260	470	1122	5022	6054	455	1460
Flax	0	264379	33702	0	1243	1595	14360	13272	173489	126553	689565
Buckwheat	2517	1532	308	1672	0	0	307	0	0	0	0
Sorghums	0	0	0	0	0	0	2467	106172	18455	1760	619
Soybeans	0	0	0	0	0	8530	3392	8594	69862	1121514	1599495
Potatoes and Sweet Potatoes	12753	27230	32523	77005	11759	38352	113715	54183	76211	17780	13419
Popcorn	0	0	0	0	0	1301	8734	0	0	0	17547
Field Seeds	0	0	0	0	0	8064	11012	0	9115	228	7768
Alfalfa	0	0	70	2106	101530	0	282776	374325	202507	447678	378696
All Other Hay	112098	282321	247321	636802	1264321	394359	209586	385581	168730	399653	417241
Vegetables	10020	558	30501	97814	0	14453	65977	23963	61125	141215	545
Value of Fruits and Nuts	1081	558	4267	14749	26809	5712	17713	8657	3748	12587	1427
Horses and Colts	294218	791715	723419	1577967	1381567	910740	958345	819894	553925	290700	80775
Mules, Donkeys, Burros	20859	26357	13529	33410	45849	45654	45146	34457	21843	10296	2397
Cattle	269776	714551	964405	1142760	2807793	1592911	2532033	1186866	2526385	4676038	6448334
Swine	122394	517383	468126	661391	2239507	1508908	2069485	535243	536794	2582424	3023138
Sheep, Lambs, Wool shorn	13163	12734	91371	136317	80320	110539	116017	272587	239349	410632	321499
Goats and Kids	0	0	283	714	55	102	287	212	61	0	60
Poultry and Poultry Products	38807	69263	223076	207916	599490	504936	927621	423580	483231	1666907	1484232
Bees and Honey Produced	35	0	1518	4487	13427	6780	10767	0	16048	0	6999
Dairy Products	84396	139437	194477	303056	560050	605250	896033	901365	519115	1121716	1184914

TABLE A.9 continued

	1954	1959	1964	1969	1974	1978	1982	1987	1992	1997
Corn (harvested for grain)	10966708	9358550	9520762	16214109	31971034	37337817	38575121	25955200	43205080	48210638
Corn (harvesed for silage)	255952	416134	795354	1153936	3776255	3903887	3084089	512075	0	0
Wheat	795	8916	4270	10530	17485	0	19153	3588	0	0
Oats	2267050	1714125	901611	954053	1110667	684031	902548	555181	231350	123691
Barley	13288	17060	336	4332	0	0	15318	0	9914	22929
Rye	104	343	624	0	0	0	0	0	0	0
Flax	0	95976	0	0	0	0	0	0	0	0
Buckwheat	0	0	0	0	0	0	0	0	0	0
Sorghums	13616	87853	90307	73286	19951	14344	0	0	0	0
Soybeans	3571093	2924647	6094438	6799745	18960839	29416154	24995936	30017359	34553922	46046357
Potatoes and Sweet Potatoes	9835	8323	1005	607	135	0	0	0	0	0
Popcorn	5105	6988	6777	0	13367	0	0	0	0	0
Field Seeds	1147	15843	915	0	0	0	0	0	0	0
Alfalfa	571640	866143	885597	1080495	1228202	1317664	1131449	855857	1221714	1044560
All Other Hay	526170	94331	151879	101373	144053	200851	159465	152514	268398	413820
Vegetables	233	254	330	0	0	0	0	0	0	0
Value of Fruits and Nuts	1615	773	2069	2360	0	0	0	0	0	0
Horses and Colts	40869	73723	3891	57475	35273	71699	121498	286500	0	0
Mules, Donkeys, Burros	0	0	0	0	0	0	0	0	0	0
Cattle	6630385	9418018	9629152	18438546	15100064	41126934	35407490	29767236	20590815	19416480
Swine	5291869	3133703	3893793	6346851	7008712	16652373	19370228	17252052	20001375	24055000
Sheep, Lambs, Wool shorn	509831	634685	347814	177429	160000	221000	566902	798641	749839	933197
Goats and Kids	0	0	0	0	0	0	0	0	0	0
Poultry and Poultry Products	1133049	1281219	1533170	801374	1364000	958000	857000	47541	2508000	4840000
Bees and Honey Produced	0	0	10	0	0	0	150000	0	0	0
Dairy Products	1204104	1507157	1824493	1946157	2084000	2082000	2419000	1969000	1347000	1361000

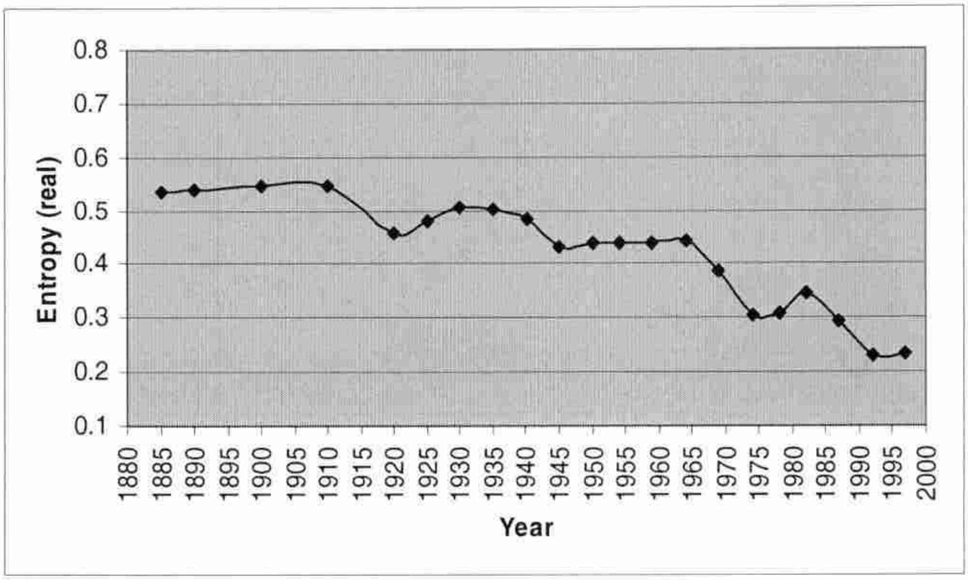
APPENDIX B: DIVERSIFICATION CHARTS WITH REAL PRICES

The diversification indexes were also computed using normalized prices (1997 = 1). The charts are presented below. The specialization trend is even more apparent, with some of the charts showing a nearly linear trend throughout the data. They show basically the same pattern as those calculated with nominal prices, but the year-to-year volatility is greater in many cases.

Normalizing the nominal price data into real price data changes the weights given to the enterprise production values of each county. Changing the price weights causes the differences observed between the nominal and real charts. Real agricultural prices have trended downward in a fairly steady manner during the past century. This accounts for the overall shifts in the real price charts and the linear trend seen for some counties.

The differences between the real and nominal charts for a specific year are explained by looking at production data for the counties. A surge in production for one type of enterprise during a certain year (without a corresponding surge in other enterprises) will cause the index to show a bigger spike in specialization when production is weighted in constant prices instead of nominal prices. There are a few spikes that attract one's attention. Decatur, Fayette, Jasper, and Linn Counties have spikes of specialization in 1935. From 1930 to 1935, Decatur saw a drastic decrease in its crop production (the result of a drought) while its dairy production remained steady. This is equivalent to a surge in dairy production, and thus, more specialization. Fayette saw a big jump in alfalfa production from 1930 to 1935, which accounts for its specialization spike.

Conversely, the introduction of a new crop will cause diversification to be accentuated when an index is calculated with real prices. This is what happened in Carroll and Decatur Counties, as they experienced a large amount of popcorn production for the first time in 1982. Their charts show the corresponding diversification spikes in that year.



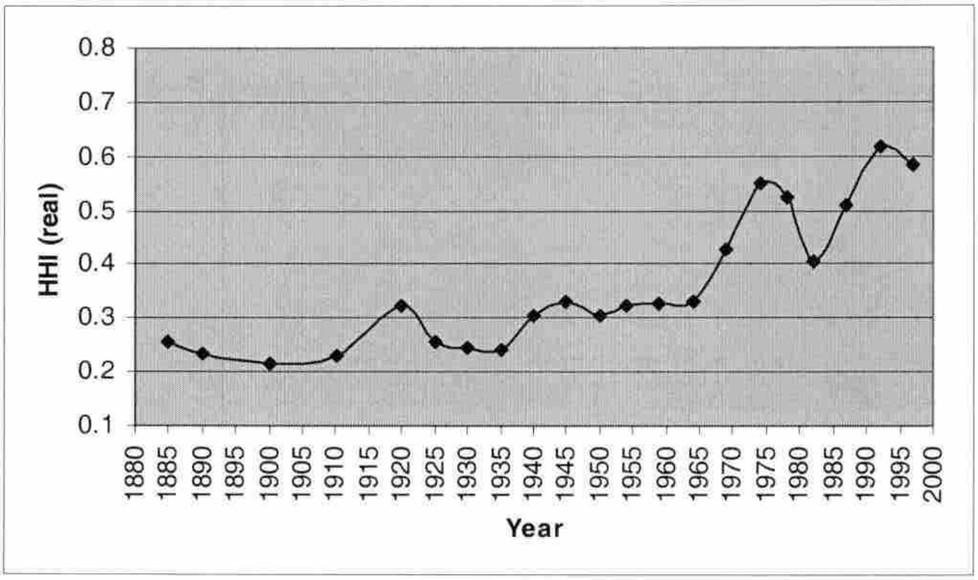
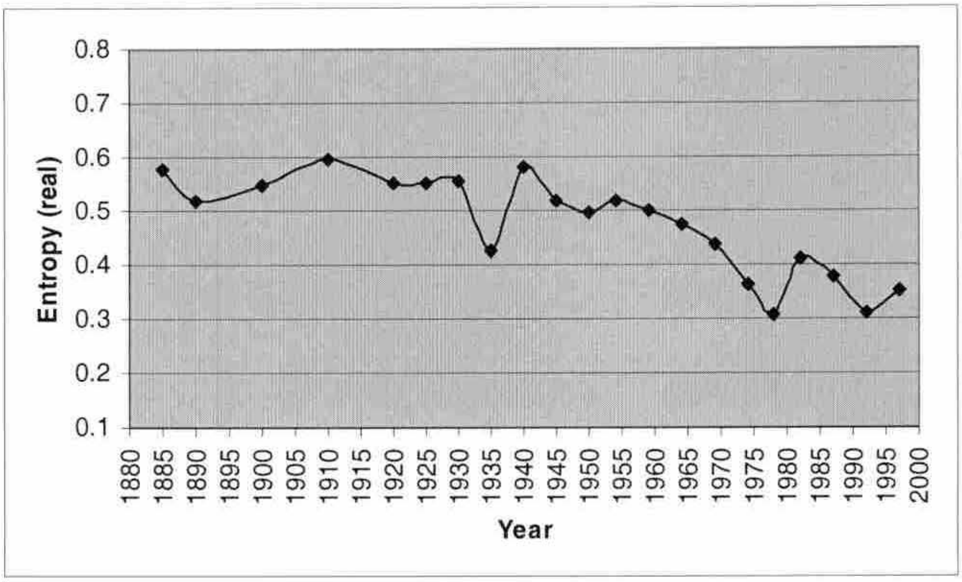


FIGURE B.1 Carroll County



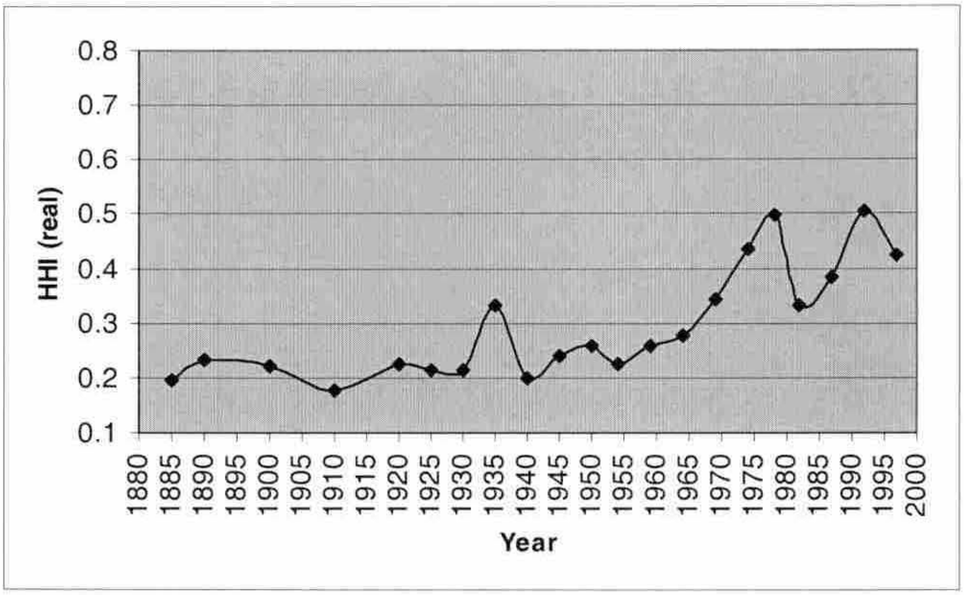
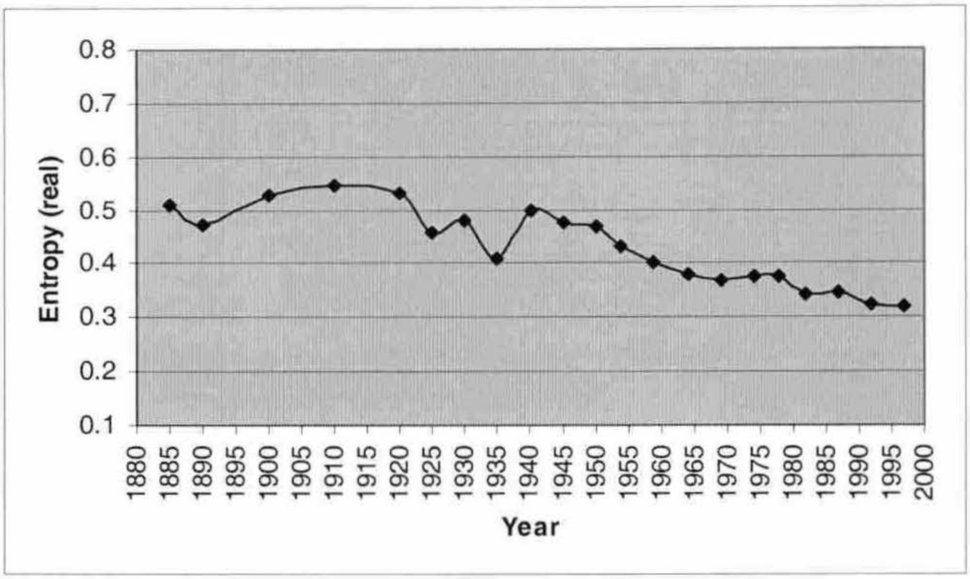


FIGURE B.2 Decatur County



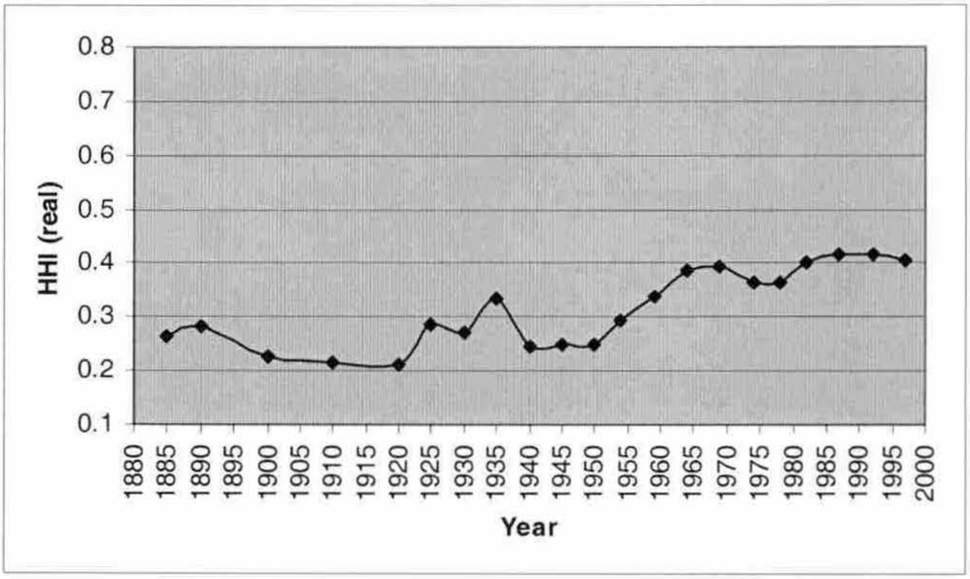
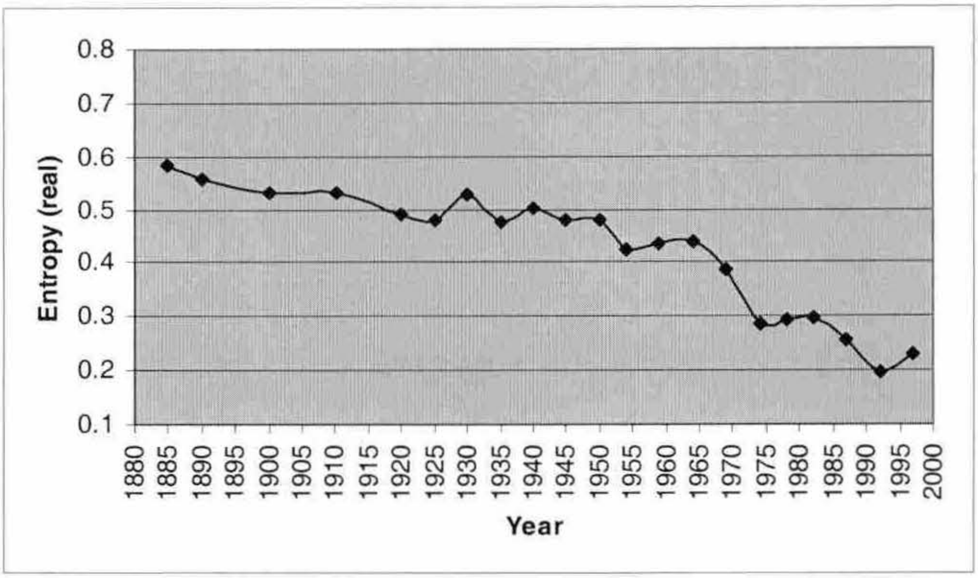


FIGURE B.3 Fayette County



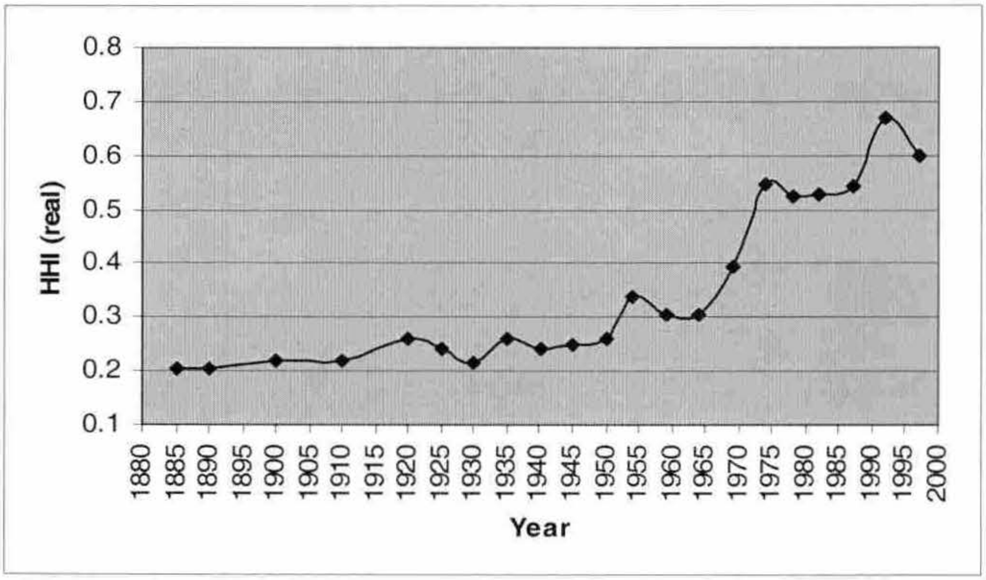
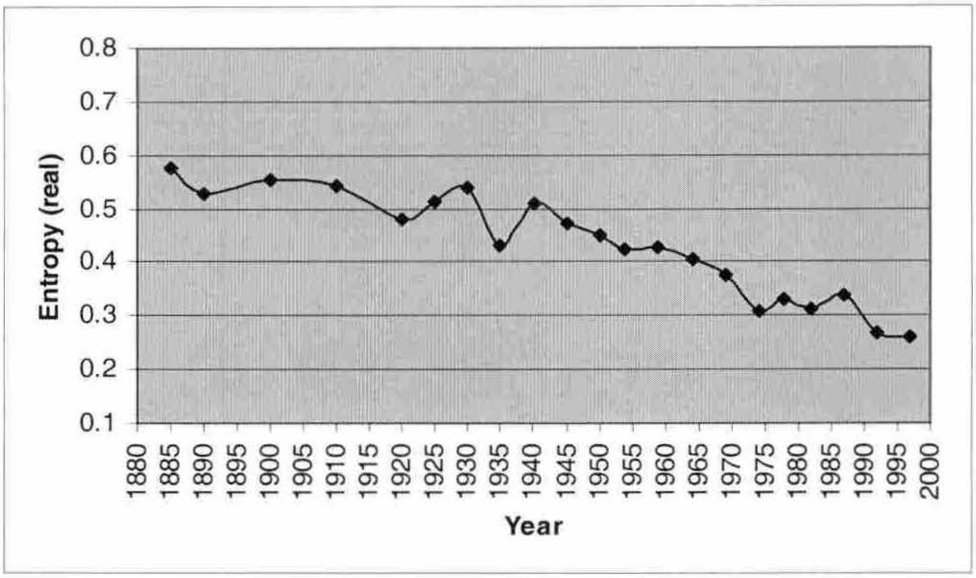


FIGURE B.4 Hancock County



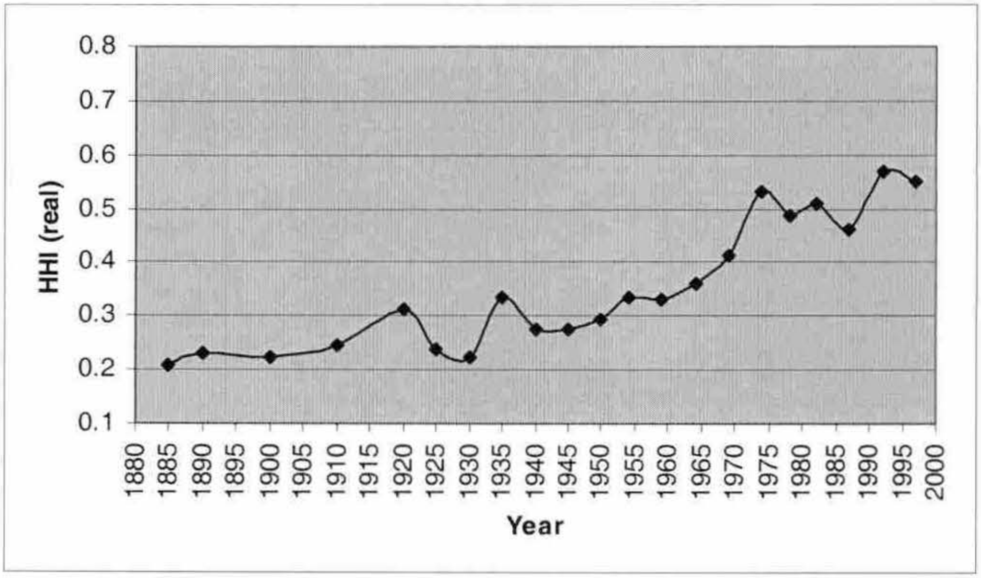
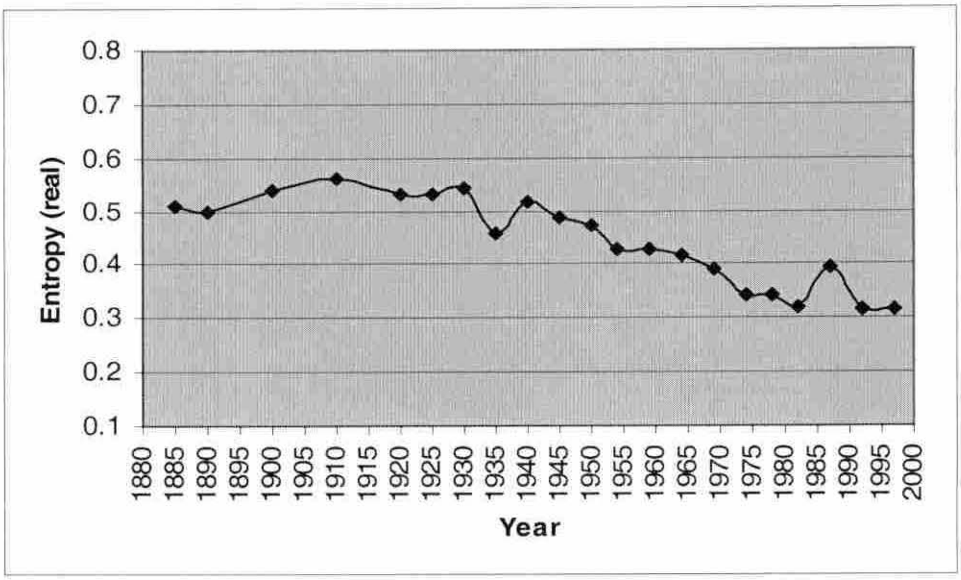


FIGURE B.5 Jasper County



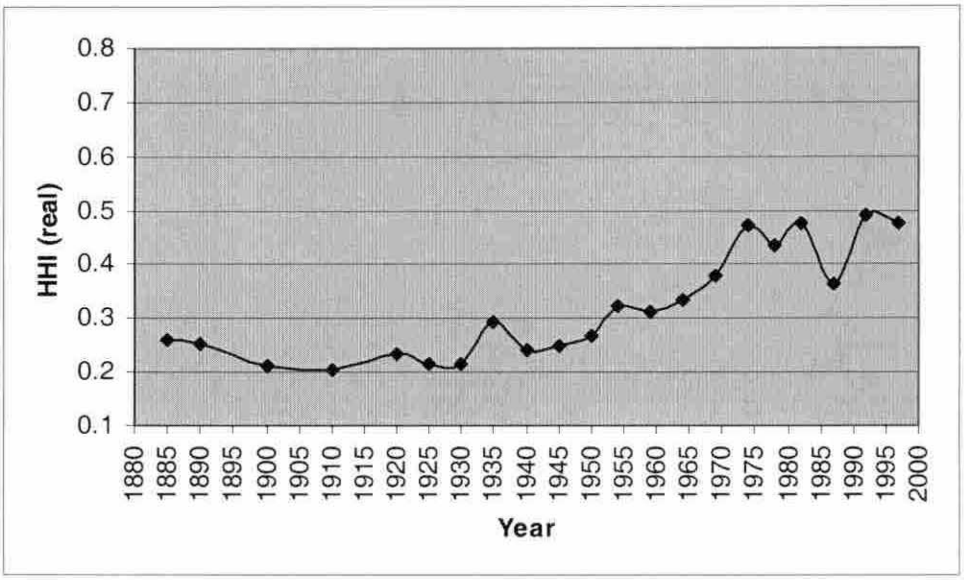
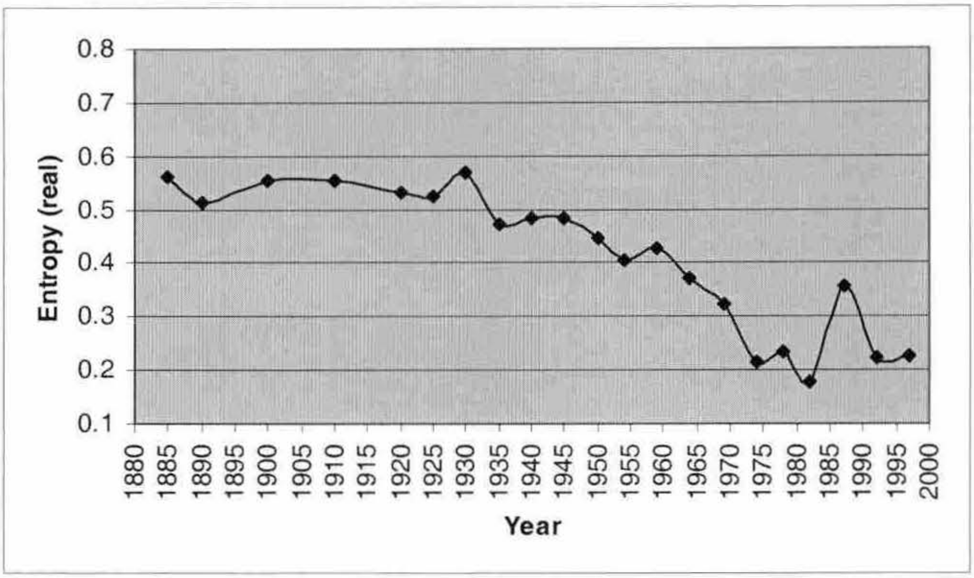


FIGURE B.6 Linn County



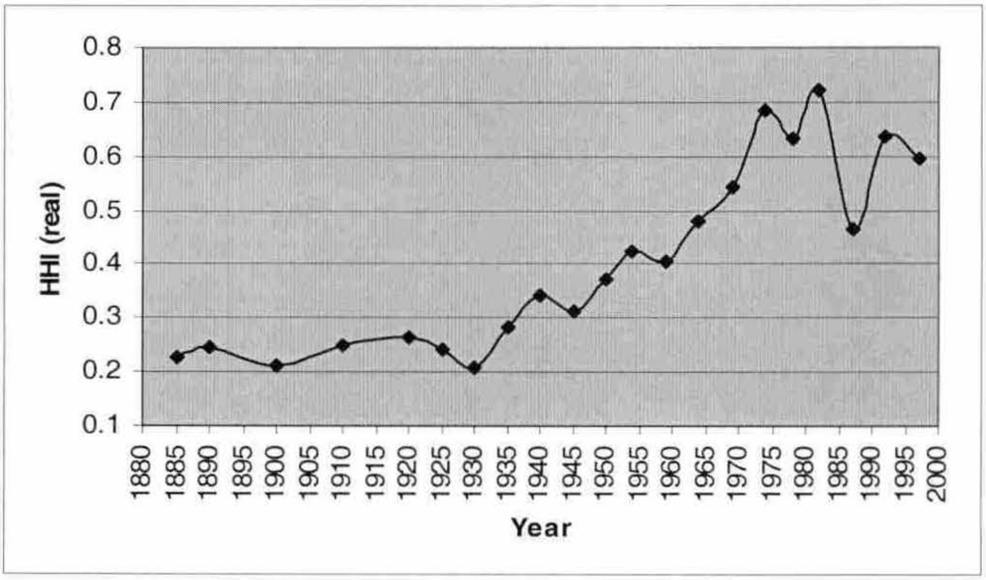
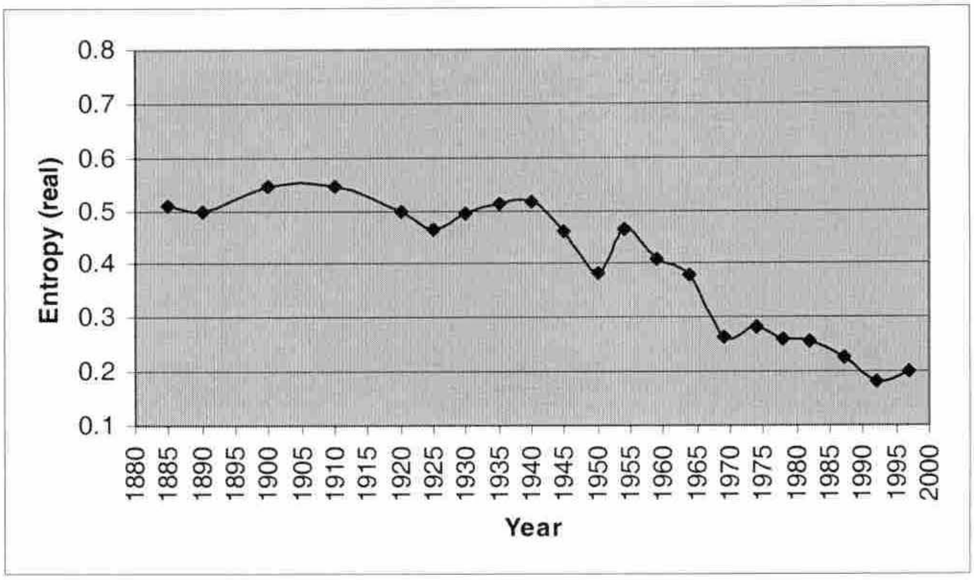


FIGURE B.7 Louisa County



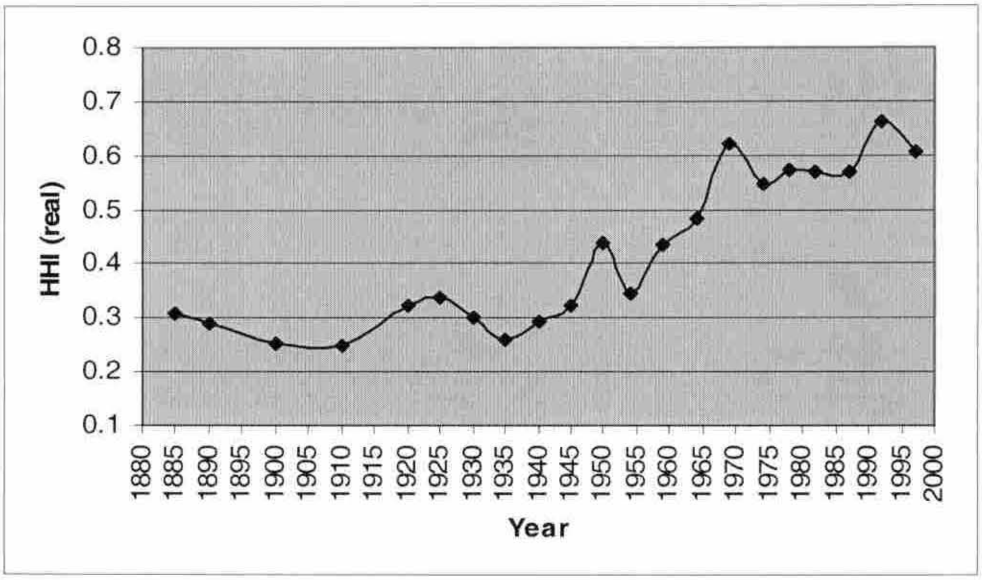
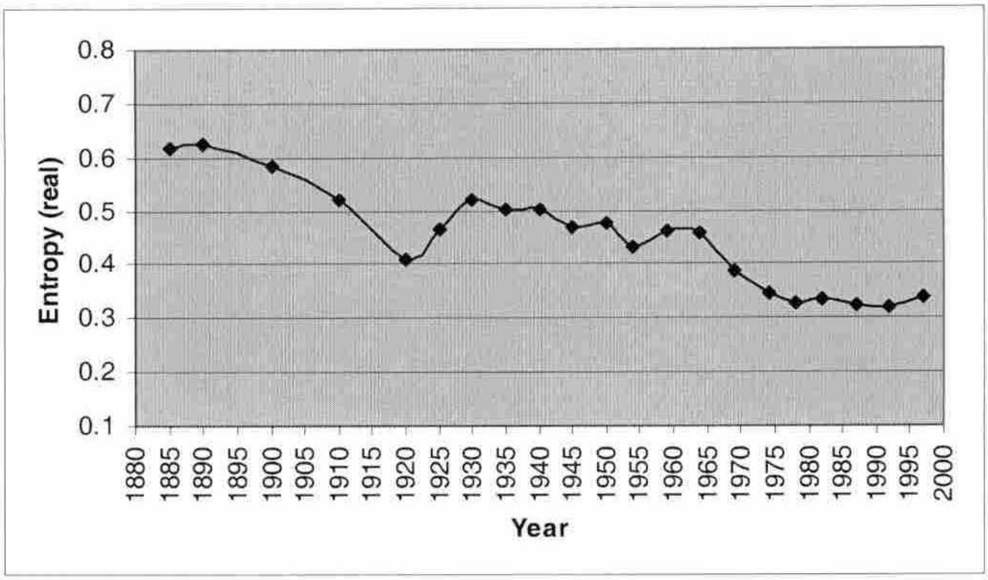


FIGURE B.8 Mills County



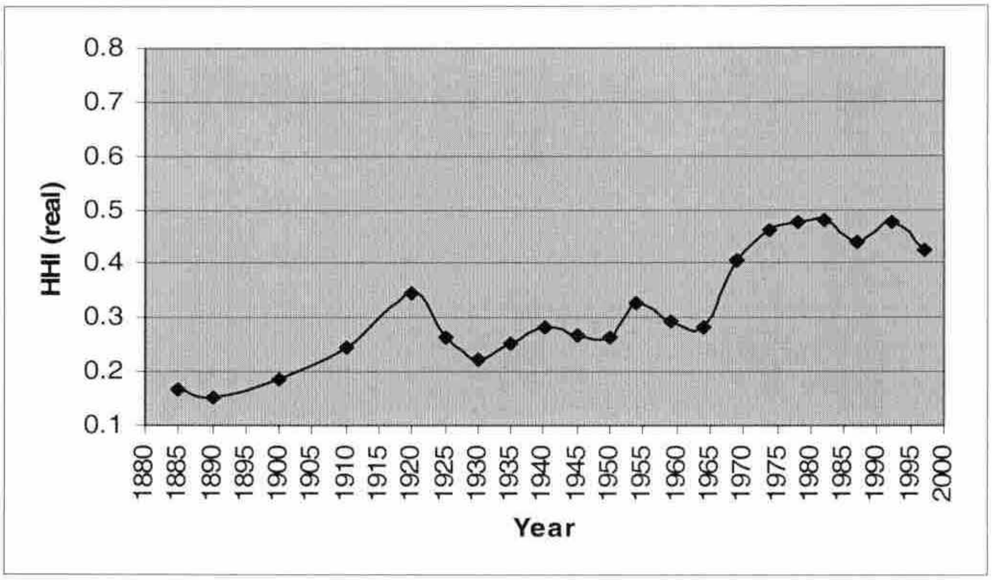


FIGURE B.9 O'Brien County

APPENDIX C: DATA FOR TECHNOLOGY PROXY

The data that served as a proxy for agricultural technology in the Granger test is a synthesis of two data sets. Table B.1 lists total public agricultural research funds from 1888 to 1990. Table B.2 lists public agricultural research funds geared specifically toward agricultural production technology from 1927 to 1995. This is the preferred data set, but since it does not begin until 1927, it was extended back by using the data set in Table B.1. The percentage of total funds spent specifically on technology was calculated for each year that the two sets overlap (1927-1990). It remained quite stable over that period and averaged 71.3%. The total funds of Table B.1 were multiplied by that figure for each year spanning 1888 to 1926, giving a good approximation of technology spending for those years. This produced the full data set given in Table B.3. It was further necessary to convert the yearly data into a set that matched the pattern of years in the index data sets. Hence, it was averaged in the manner of

$$\left(\sum_{i=-2}^{2} t_i \right) / 5$$

where t_i is each year of the index data sets (1885, 1890, 1900,…,1997). The full data set does not quite cover the endpoint years, 1885 and 1997. The 1888 value, 12,018,629, was used for 1885, while the 1995 value, 1,181,250,531, filled the gap at 1997. The final data set is presented in Table B.4.

TABLE C.1 USDA and SAES total agricultural research expenditures (1888-1990)

Year	Dollars	Year	Dollars	Year	Dollars
1888	18,347,000	1923	240,644,000	1957	688,721,000
1889	18,284,000	1924	248,411,000	1958	780,386,000
1890	24,280,000	1925	292,522,000	1959	790,595,000
1891	23,881,000	1926	316,823,000	1960	797,961,000
1892	26,834,000	1927	309,654,000	1961	834,975,000
1893	24,777,000	1928	333,513,000	1962	850,763,000
1894	27,477,000	1929	395,864,000	1963	890,478,000
1895	29,736,000	1930	490,188,000	1964	948,845,000
1896	30,863,000	1931	502,340,000	1965	1,015,878,000
1897	30,929,000	1932	478,035,000	1966	1,037,471,000
1898	31,624,000	1933	449,919,000	1967	1,064,232,000
1899	29,716,000	1934	420,588,000	1968	943,524,000
1900	29,501,000	1935	439,093,000	1969	994,813,000
1901	35,211,000	1936	446,136,000	1970	1,023,863,000
1902	39,013,000	1937	425,455,000	1971	1,057,756,000
1903	41,068,000	1938	473,025,000	1972	1,225,284,000
1904	45,637,000	1939	542,847,000	1973	1,241,106,000
1905	45,256,000	1940	525,768,000	1974	1,226,311,000
1906	60,223,000	1941	518,292,000	1975	1,292,842,000
1907	71,190,000	1942	499,004,000	1976	1,699,247,000
1908	81,594,000	1943	501,973,000	1977	1,456,359,000
1909	93,874,000	1944	467,308,000	1978	1,499,231,000
1910	97,057,000	1945	488,099,000	1979	1,486,898,000
1911	110,556,000	1946	494,041,000	1980	1,586,152,000
1912	120,203,000	1947	620,316,000	1981	1,633,163,000
1913	120,203,000	1948	711,785,000	1982	1,601,193,000
1914	124,262,000	1949	614,021,000	1983	1,547,481,000
1915	149,878,000	1950	521,680,000	1984	1,541,835,000
1916	140,730,000	1951	510,081,000	1985	1,590,877,000
1917	124,544,000	1952	543,410,000	1986	1,597,089,000
1918	129,637,000	1953	545,503,000	1987	1,624,754,000
1919	139,661,000	1954	596,074,000	1988	1,747,860,000
1920	130,131,000	1955	623,809,000	1989	1,638,633,000
1921	171,132,000	1956	613,833,000	1990	1,652,242,000
1922	231,111,000				

source: Dr. Wallace Huffman, Iowa State University

TABLE C.2 USDA and SAES agricultural research expenditures focused on technology (1927-1995)

Year	Dollars	Year	Dollars
1927	229,865,599	1962	612,357,413
1928	258,328,411	1963	648,878,788
1929	279,964,897	1964	684,527,729
1930	316,296,060	1965	719,520,617
1931	333,030,453	1966	738,716,484
1932	332,210,732	1967	765,170,017
1933	305,250,801	1968	719,830,348
1934	279,288,692	1969	779,087,304
1935	298,050,412	1970	745,794,559
1936	318,566,673	1971	766,878,924
1937	326,271,506	1972	794,666,019
1938	380,349,471	1973	822,260,631
1939	392,329,634	1974	825,655,647
1940	403,150,147	1975	843,159,831
1941	410,009,180	1976	919,480,995
1942	394,952,814	1977	998,319,830
1943	405,931,351	1978	1,022,906,553
1944	424,827,374	1979	1,041,412,196
1945	445,461,501	1980	1,037,067,406
1946	472,630,448	1981	1,074,878,845
1947	513,951,428	1982	1,118,293,591
1948	504,385,373	1983	1,151,833,022
1949	443,247,286	1984	1,129,071,736
1950	320,334,792	1985	1,103,631,073
1951	326,728,353	1986	1,087,555,994
1952	347,787,226	1987	1,115,577,491
1953	357,344,428	1988	1,119,209,223
1954	378,750,761	1989	1,126,565,748
1955	422,042,218	1990	1,151,694,955
1956	439,027,522	1991	1,177,001,321
1957	472,414,035	1992	1,185,244,034
1958	537,487,799	1993	1,177,620,369
1959	538,753,671	1994	1,191,293,011
1960	558,291,032	1995	1,181,250,531
1961	590,014,286		

source: Dr. Wallace Huffman, Iowa State University

TABLE C.3 USDA and SAES agricultural research expenditures focused on technology (1888-1995)

Year	Dollars	Year	Dollars	Year	Dollars
1888	12,018,629	1924	177,065,468	1960	558,291,032
1889	13,032,696	1925	208,507,453	1961	590,014,286
1890	17,306,599	1926	225,829,020	1962	612,357,413
1891	17,022,195	1927	229,865,599	1963	648,878,788
1892	19,127,071	1928	258,328,411	1964	684,527,729
1893	17,660,857	1929	279,964,897	1965	719,520,617
1894	19,585,396	1930	316,296,060	1966	738,716,484
1895	21,195,594	1931	333,030,453	1967	765,170,017
1896	21,998,911	1932	332,210,732	1968	719,830,348
1897	22,045,956	1933	305,250,801	1969	779,087,304
1898	22,541,346	1934	279,288,692	1970	745,794,559
1899	21,181,338	1935	298,050,412	1971	766,878,924
1900	21,028,088	1936	318,566,673	1972	794,666,019
1901	25,098,133	1937	326,271,506	1973	822,260,631
1902	27,808,169	1938	380,349,471	1974	825,655,647
1903	29,272,957	1939	392,329,634	1975	843,159,831
1904	32,529,706	1940	403,150,147	1976	919,480,995
1905	32,258,132	1941	410,009,180	1977	998,319,830
1906	42,926,496	1942	394,952,814	1978	1,022,906,553
1907	50,743,690	1943	405,931,351	1979	1,041,412,196
1908	58,159,581	1944	424,827,374	1980	1,037,067,406
1909	66,912,672	1945	445,461,501	1981	1,074,878,845
1910	69,181,490	1946	472,630,448	1982	1,118,293,591
1911	78,803,474	1947	513,951,428	1983	1,151,833,022
1912	85,679,783	1948	504,385,373	1984	1,129,071,736
1913	85,679,783	1949	443,247,286	1985	1,103,631,073
1914	88,573,007	1950	320,334,792	1986	1,087,555,994
1915	106,831,896	1951	326,728,353	1987	1,115,577,491
1916	100,311,272	1952	347,787,226	1988	1,119,209,223
1917	88,774,014	1953	357,344,428	1989	1,126,565,748
1918	92,404,266	1954	378,750,761	1990	1,151,694,955
1919	99,549,297	1955	422,042,218	1991	1,177,001,321
1920	92,756,385	1956	439,027,522	1992	1,185,244,034
1921	121,981,586	1957	472,414,035	1993	1,177,620,369
1922	164,734,160	1958	537,487,799	1994	1,191,293,011
1923	171,529,210	1959	538,753,671	1995	1,181,250,531

TABLE C.4 Final data set for technology proxy

Year	Dollars
1885	12,018,629
1890	15,701,438
1900	23,531,415
1910	71,747,400
1920	114,285,139
1925	202,559,350
1930	303,966,111
1935	305,485,617
1940	396,158,249
1945	452,560,420
1950	388,496,606
1954	388,990,431
1959	539,392,165
1964	680,800,206
1969	755,352,230
1974	841,044,625
1978	1,003,837,396
1982	1,102,228,920
1987	1,110,507,906
1992	1,176,570,738
1997	1,181,250,531

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