PRICING EFFICIENCY IN THE U.S. HOG FUTURES MARKET

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ABSTRACT

Numerous research efforts have tested the pricing efficiency of the hog futures market. However, the definitive conclusion of those tests has not yet been established.

The objectives of this study were:

(1) to identify the structural relationships among the factors which affect the price of live hogs;

(2) to formulate the econometric model in order to forecast the live hog prices; and

(3) to examine the pricing efficiency of the hog futures market by investigating the relationship among spot prices, expected spot prices, and futures prices of live hogs.

Time series and econometric methods were used to predict the hog prices.

The following conclusions were drawn:

(1) This study shows that the predicted price is the unbiased estimate of the subsequent spot price.

(2) There is a pricing inefficiency in the live hog futures market. If the producers wish to achieve allocative efficiency, then they should base their production decision on using the predicted price of hogs from the model and the live hog futures price together.

A misallocation of resources may result in a reduction in economic surplus of the hog producers.

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CHAPTER I

INTRODUCTION

1.1 The Problem Statement

Agricultural production is affected by uncertainty because farm production takes time, in certain cases up to many months. Consequently, financial outcomes must be estimated when production decisions are made. Production plans have led to disappointing financial results because future prices were not those expected. As long as estimates of future prices are subject to the impact of uncertainty, the use of resources will be different than if future prices could be foreseen more accurately.

One of the main functions of futures markets is to improve price expectations which farmers use in making production decisions. The spot price of a commodity is determined by negotiations between the buyer and the seller of the physical commodity. In contrast, futures prices are determined by competitive bidding for and offering of futures contracts by open outcry and reflect trader expectations of futures prices, as well as the current economic situation. It might be presumed that prices in futures markets could be used to offer a satisfactory check on the accuracy of price expectations. In such a case as mentioned above, the producers do not need to form any kind of expectations. They only observe futures prices to determine their production.

In general, the literature regards the futures markets as a tool for predictions of the expectation level of the subsequent spot price, as well as a mechanism for agents to trade. There is a growing body of evidence which suggests that hog producers' utilization of the futures market would have the potential to dampen the production cycle (Stein, 1991).

At the very least, agents are aware of futures prices when they make allocative decisions; therefore, futures prices affect resource allocation in the spot market. The forward prices generated in the futures market are used by the industry in making production, marketing, and inventory decisions. If the prices in these markets do not accurately reflect current and expected supply and demand conditions, a misallocation of resources may result.

The term "efficiency" has several different meanings. In an economic sense, efficiency in the allocation of scarce resources means allocating these resources so that the best use is made of them. The mechanism for allocating these resources is the pricing mechanism of the market system. If futures prices provide accurate signals for resource allocation, hog producers are able to make correct production-investment decisions and to choose the most suitable futures for investment. These choices are only possible if the market is efficient; that is, if futures prices fully reflect all available information.

Thus, the primary function of a futures market is to allocate resources to the most profitable investment opportunities through price discovery.

Inherent in the efficient market is the recognition that the parties involved should obtain a normal return on their capital investment but not an above-average return, which results from imperfections in the futures market. If there are certain imperfections in the futures market, the wise investor will attempt to utilize these to achieve a better-than-average return by following a trading strategy based on either business and economic indications or market statistics.

The controversy over the efficiency of futures markets came into sharp focus with empirical studies. Many investigators have examined the pricing efficiency of agricultural futures markets. However, those studies differ from each other with respect to the commodities examined, the time periods, methods of analysis, and the type of data employed. Since a wide range of variability exists in the conclusions, definitive statements regarding the efficiency of futures trading are difficult to make, despite the available theoretical base for evaluating market performance.

Econometric models may be used instead of the futures price to forecast the subsequent spot price of a commodity. Econometric models often allow expectations to play a key role in determining future prices. However, producers still have the problem of choosing among rival economic models.

The cobweb model may not be the most appropriate forecasting model from an economic viewpoint because the producer in the cobweb model forms expectations on past price history alone. Rational expectations are more consistent with the underlying structure of economic behavior of hog producers, whereas naive, extrapolative, and adaptive expectations are not necessarily compatible with economic structure. The producer in the rational expectations model forms price expectations based on the structural parameters of the demand and supply equations and exogenous information.

Thus, incorrectly imposing the assumption of expectations (past prices) on the econometric model can lead to unreasonable estimates of important parameters. Therefore, the assumption of rational expectation can be a useful working hypothesis in the forecasting model.

Hog producers may be unable to formulate and evaluate a rational expectations econometric model because of the lack of expertise, resources, and time. Therefore, they may rely on readily available information, such as that provided by the Chicago Mercantile Exchange. Then the question arises, is it better for producers to use the futures price, or to form price expectations when they need to plan their production?

1.2 Objectives

The overall objective of this research is to investigate pricing efficiency in the U.S. hog futures market during 1975-1990. The specific objectives are to:

(1) Identify the structural relations and factors which affect the price of hogs;

(2) Formulate econometric models of the U.S. hog market to forecast hog prices at the farm level; and

(3) Examine the pricing efficiency of live hog futures by investigating the relationship between spot price, expected spot price, and futures price.

The benefits of this study are to provide the basis for improving the hog producer's ability to forecast future prices. There are two methods—the futures price and the econometric model—that can be used by the hog producer to forecast the subsequent spot price needed for production planning. If the hog futures market is inefficient, then the econometric model should be used instead of futures prices. However, if the live hog futures market is efficient, then the hog producer can make a good decision using available prices, either cash or futures. This study provides hog producers, as well as professional traders, with a low-cost mechanism to formulate forecasts of subsequent spot prices. Consequently, the study increases market information, enabling producers in the spot market to respond more rapidly to expected supply and demand conditions.

If market prices reflect all relevant information as fully as possible, then agents whose decision making is based on current prices are responding to the most useful signals the market can provide. If the market is efficient in the above sense, then the current spot and futures prices can be expected to be unbiased anticipations of subsequent spot prices. This not only assists markets in price discovery, but also facilitates the intertemporal allocation of economic resources by minimizing the costs of agents who use futures prices for hedging purposes.

CHAPTER II

REVIEW OF LITERATURE

In this chapter, the following subjects are successively discussed: (1) Producers' Price Expectations: Theoretically, (2) Producers' Price Expectations: Empirically, (3) Hog Models, (4) Hog Models with Price Risk, (5) The Relationship Between Efficient Market Hypothesis, and Rational Expectations Hypothesis, (6) Rational Price Expectations or Futures Price as a Predictor of Subsequent Spot Price, (7) Estimation Technique for Rational Expectations Model and (8) Test of Rational Expectations.

2.1 Producers Price Expectations: Theoretically

Economists have long recognized the importance of expectations theory in macroeconomics. In early attempts to develop such a theory, anticipations of the value of variables were assumed to depend upon recent experiences.

2.1.1 Naive Expectations

Ezekiel (1938) in his article on the cobweb theorem, assumed that the expected price of suppliers was equal to the latest known price,

$$E[P_t \mid \text{information at } t-1] = P_{t-1}, \tag{2.1}$$

where $E[P_t]$ is the expected price at time t based on information at time (t-1).

The cobweb model assumes that farmers have static or constant expectations. Formally the model can be stated as follows:

$$Q_t^d = f(P_t) \text{ -- Demand function,} \tag{2.2}$$

$$Q_t^s = f(EP_t) \text{ -- Supply function,} \tag{2.3}$$

$$EP_t = P_{t-1} \text{ -- Static expectation.} \tag{2.4}$$

$$Q_t^d = Q_t^s \text{ -- Equilibrium condition.} \tag{2.5}$$

These equations give rise to a simple dynamic model (formally represented by a first-order difference equation) with fluctuations in price which either converge to a stable long-run equilibrium value, diverge/explode, or oscillate constantly around the equilibrium, depending on the relative slopes of the demand and supply curves. Figure 2.1 shows a cobweb converging to price P_e and quantity Q_e.

According to Figure 2.1, 0A and 0B are the market price and quantity in equilibrium. In the first period, there is a positive excess demand for the commodity; and since supply is constant, there will be a tendency for the price to rise to 0C in the rest period. If, however, the price is raised to 0C, the firm wishes to sell 0D, and in the second period they will produce the quantity of the commodity. But the price will fall to 0E, which is less than 0C, if the firms actually offer 0D. The excess demand, at this price, is less

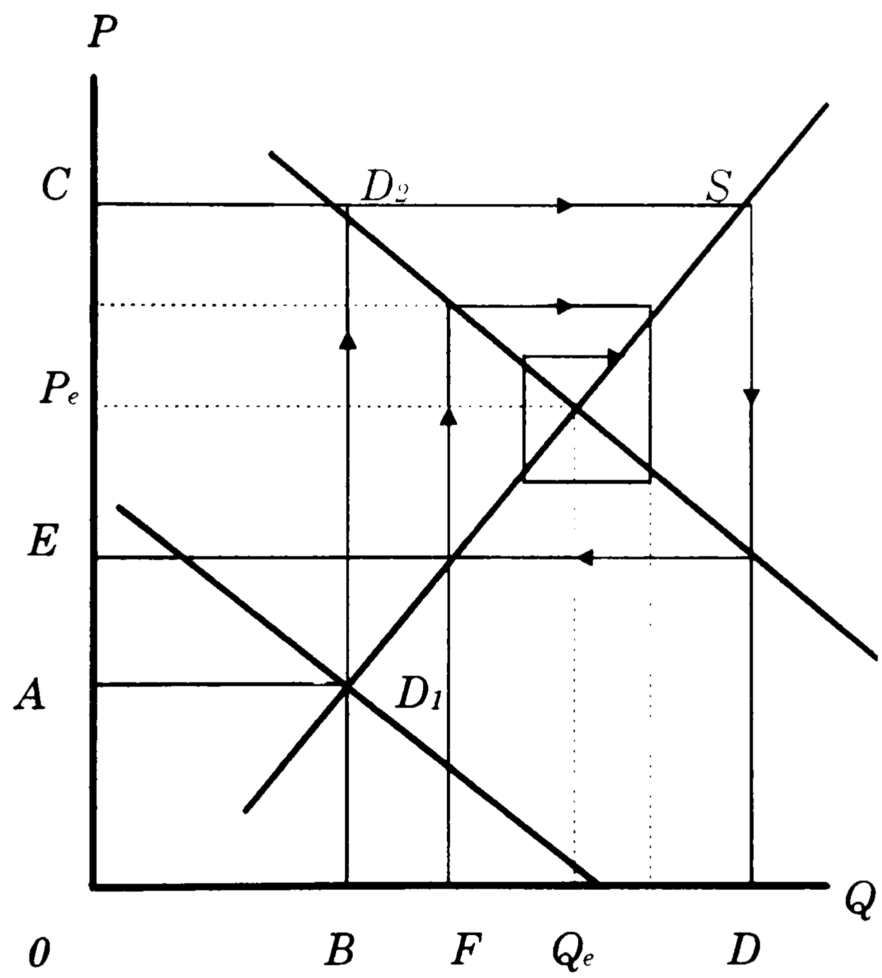


Figure 2.1. Cobweb Model.

Source: Oskar Lange, Introduction to Econometrics (1978), p. 162.

than what it was when the price was to be 0A. The price and quantity will eventually converge to the new equilibrium price and quantity.

The cobweb model (with naive expectation) does not attract much theoretical support, since it assumes that farmers conduct their business in a most naive manner. First, the assumptions ignore the impact of similar actions of all other farmers. Suppose prices at a given point are high. This will encourage producers to produce more hogs, which will be placed on the market in the next time period. But a large supply will lower prices, and then reduced prices will motivate farmers to produce less during the next period. Using this knowledge, the crafty producers can produce countercyclically in order to gain profits. If most producers are irrational, then the rational producers can realize large profits.

Second, the cobweb model assumes that farmers do not learn from their experience. The cobweb market follows a very regular pattern, namely, oversupply, undersupply, oversupply, undersupply, and so on.

2.1.2 Extrapolative Expectation

Metzler (1941) introduced the idea of extrapolative expectations, which is based on the fact that future expectations should be based not only on the past level of an economic variable, but also on its direction of change. Thus, if P_{t-1} represents the price level in period (t-1) and P_{t-2} the price level in period (t-2), the extrapolative prediction for period t is defined as:

$$EP_t = P_{t-1} + \delta(P_{t-1} - P_{t-2}), \tag{2.6}$$

where δ is called the coefficient of expectation. The extrapolative expectation in any period is equal to the price level in the previous period plus (or minus) some portion of the change between the previous two periods.

Goodwin (1947) experimented with the extrapolative hypothesis in which expected prices were related to previous prices and their latest change. There is no element of learning involved in this process. The behavior of the cobweb model with extrapolative expectations is governed by the value of the coefficient, δ, the best choice of which depends upon the underlying economic structure of the model. In this case, negative values of δ, are appropriate. High prices stimulate production, which increases supply in the subsequent period and causes lower prices. In other words, price trends can be reversed rather than maintained from year to year. This is a simple demonstration of the notion that the appropriate expectations mechanism depends upon the structure of the model.

2.1.3 Adaptive Expectations (AE)

Nerlove (1958) analyzes a cobweb model in which the adaptive expectation hypothesis replaced the extrapolative expectation hypothesis.

Using the same symbols as above, the adaptive expectation, made in period (t-1), of the price level in period t is defined as:

$$EP_t = EP_{t-1} + e(P_{t-1} - EP_{t-1}), \qquad (2.7)$$

where e is called the coefficient of adaptation and e lies between zero and one. Thus, with adaptive expectations, the expected value in the next period is equal to the expectation for current period plus or minus a proportion of the error in the expectation for the current period. This formation suggested that producers revised their expectations in each period in proportion to the difference between actual price and the previously expected "normal" price.

The adaptive equation has often been associated with error learning. First, if one's expectations are correct, they will not revise them, implying that P_{t-1} is equal to EP_{t-1}. Second, if one's expectations prove to be incorrect, they will revise them $P_{t-1} \neq EP_{t-1}$

More precisely, adaptive expectations are expressed as a weighted average (an infinite sum) of past prices; that is,

$$EP_t = e\sum_{i=1}^{\infty}(1-e)^{i-1}P_{t-i} \qquad (2.8)$$

where

EP_t = adaptive expectation of price at time t,

P_{t-i} = price at time t-i, and

e = a constant between the values of 0 and 1.

This formula suggests that changes in expectations will occur slowly over time as past data change. People use more information than just past data on a single variable to form their expectations of that variable.

Nerlove (1958) developed a cobweb model with a learning process:

$$Q_t^d = a - bP_t, \tag{2.9}$$

$$Q_t^s = c + dEP_t \tag{2.10}$$

$$Q_t^d = Q_t^s \tag{2.11}$$

$$EP_t = EP_{t-1} + e(P_{t-1} - EP_{t-1}). \tag{2.12}$$

This model reduces to a first-order difference equation in P_t. The long-run equilibrium solution is

$$P = \frac{a-c}{b+d}, \tag{2.13}$$

which permitted producers to assert expectations that are correct only when the market is in equilibrium. The equilibrium price is identical to the long-run equilibrium price of the naive static model.

The definite solution, given $P_t = P_0$ when t = 0, is

$$P_t = P + (P_0 - P)\{1 - e(1 + d / b)\}^t, \tag{2.14}$$

a necessary and sufficient condition for stability is

$$\{1 - e(1 + d/b)\} < 1. \tag{2.15}$$

In the extreme case of adaptive expectations, e=1 and the inequality reduces to the naive cobweb stability condition.

Manipulating the equations, Mills (1961) yielded the time path for expectational errors:

$$EP_t - P_t = \lambda^t (EP_t - P_0) \text{ for } t = 1,2,3,\ldots, \tag{2.16}$$

where λ is $[(d/b-1)e+1]^t$ and P_0 and EP_0 are the initial actual and expected prices, respectively. Mills (1961) states,

> Thus, in [an] adaptive expectations model, expectations are not only always wrong whenever the model is out of equilibrium, but they are wrong in a very simple and systematic way. Presumably, an intelligent decision maker would be able to observe such biases in his expectations and would refrain from using the method by which such expectations were formed. (pp. 332-333)

Adaptive expectations became generally accepted, although it was recognized that it denied the effect of information other than past experience in formulating those expectations. Although simple and useful, adaptive expectations are not very convincing, especially in regard to the way expectations are formed. Under the assumption of AE, the expected price level depends solely on past price levels. Future events which might affect the price level are totally ignored. Yet there are obvious problems associated with the use of an adaptive expectations mechanism. The mechanical application of an adaptive expectations formula, therefore, does not necessarily make the best use of all the information available. For this reason, it is suspect as a description of economic behavior.

Doorn (1975) explains that the cobweb model is just a first step in the development of micro-dynamic theory. The cobweb model concentrates on intertemporal adjustment processes, but ignores the aspects of price adjustment under uncertainty.

Maddock and Carter (1984) show that an extrapolative expectation is based only on the information contained in the actual values of price for the preceding two periods. An adaptive expectation, on the other hand, is based on the entire past history of the price series.

To check whether this is a cobweb type model or not, Muth (1961) indicated that the expected price (using hog-corn price to base their production plan) is a negative relationship with the actual price (see Figure 2.2).

Lange (1978), Hamouda and Rowley (1988), and Brennan and Carrol (1987) showed the relationship between quantity supplied at quarter t and price of commodity at time in opposite directions. Figure 2.2 shows the negative relationship between prices and outputs in the same quarter.

If farmers possess "rational expectations," some crafty farmers would perceive the price pattern and would plant more (put more pigs in the confinement house) in years following low prices in anticipation that most farmers would plant less (put less pigs in the confinement house)

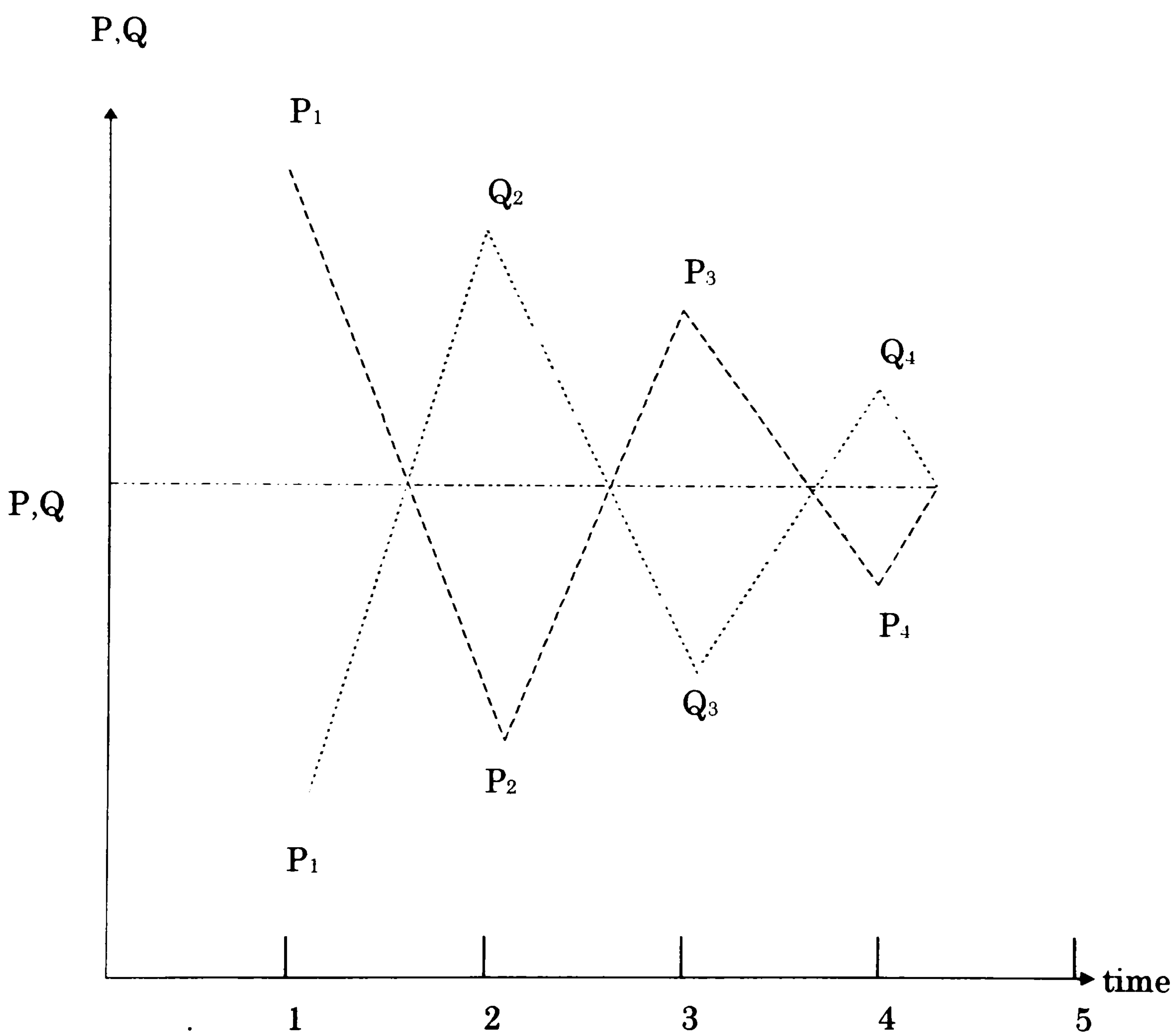


Figure 2.2. Fluctuating Cobweb.

Source: Oskar Lange, Introduction to Econometrics (1978), p. 162.

(Clower et al., 1988). In this case, producers can counter cyclical production. They base their production on the demand curve (or close to demand curve) because they realize that the cobweb cycle still exists.

A major breakthrough came in a paper published by Muth (1961). Muth offers a strong argument that the adaptive expectations model is wrong. He considers that rational economic behavior would look at whatever relevant economic information is available to form expectations, and the information is incorporated efficiently into unbiased expectations about the future. Muth finds support for his idea in the behavior of agricultural prices.

2.1.4 Rational Expectations (RE)

Muth's theory is that the Rational Expectations Hypothesis (REH) assumes farmers know the structure of the market and base their expectation/forecast of next period's price on this information. The forecast can be either with uncertainty or without uncertainty. Without uncertainty, farmers will have perfect foresight and their expectation will be the long-run equilibrium price, so there will be no fluctuations in the price.

The RE hypothesis states that the subjective expectation of any variable is the same as the objective expectation of the price based upon the true model (the agents in the market are assumed to know the structure of the model and use this information in order to form their expectation). The producer, according to RE, forms the price expectations using the model parameters and exogenous information. By contrast, producers in the cobweb model form expectations on the past price which show their habit persistence.

Rodano (1984) explained how to use the Perfect Foresight Approach (PFA) as a substitute for the Rational Expectations Hypothesis (REH) if the absence of uncertainty assumption is retained. He stated that

> The PFA is defined as that hypothetical situation in which the laws governing the economic system are known to all. Therefore, each trader is capable of calculating the equilibrium price associated with any future date. (p. 29)

In Figure 2.3, the producer will produce P_E at price O_E. With uncertainty, price fluctuations may, therefore, occur from period to period, but this will be random and not systematic as in a static expectations model (constant expectations). The implications of introducing RE into the cobweb model are that systematic situations disappear. In Figure 2.3, the actual future price will differ from the expected price because of unanticipated shocks (e.g., weather). Price fluctuation may be random and not systematic.

Muth (1961) assumes that rational maximizing behavior on the part of economic agents is the same as the predictions of the relevant economic theory. Or, more precisely, for the same information set, the subjective probability distribution of outcomes of firms tends to be distributed about the objective probability distribution for outcomes of the theory. Then, the

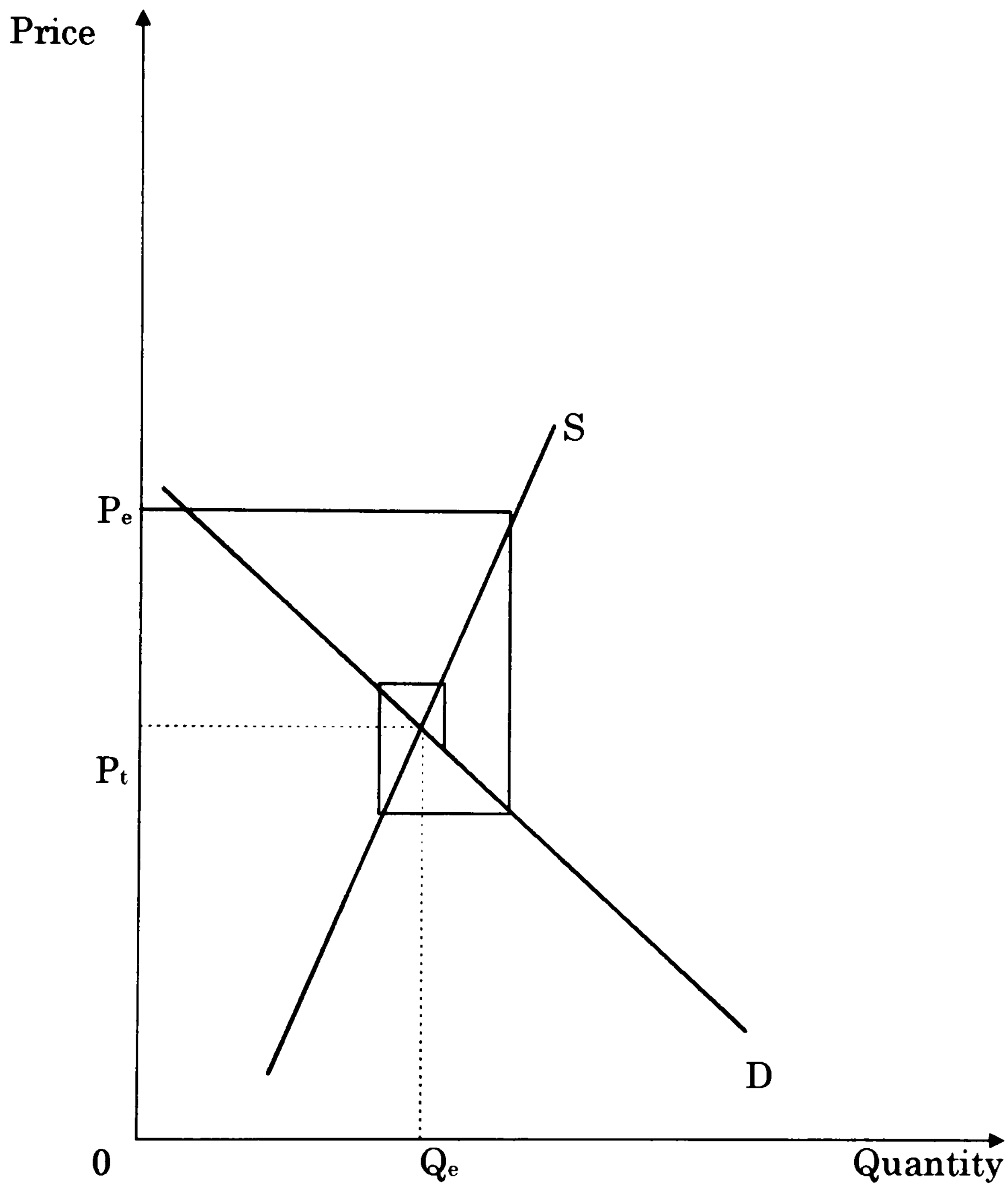


Figure 2.3. Perfect Foresight Equilibrium.

Source: Bob Beachill, "Rational Expectations," The Journal of the Economics Association Fall 1987, p. 68.

expected values of the variable to be forecast and the actual values have the same probability distribution (same mean).

Nelson (1975) shows that the forecasts, based on the structure of a system and the exogenous inputs to that system, will be more accurate than purely extrapolative forecasts. It should be clear that the rational expectations must be more accurate than the "best" extrapolative prediction in the sense of having smaller mean square errors, since the conditioning information set of rational expectations presumes the past history of thevariable being predicated. Thus, in the present example,

$$P_t = E(P_t \mid Y_{t-1}, Y_{t-2}, \ldots; P_{t-1}, P_{t-2}, \ldots) \qquad (2.17)$$

is the minimum squared error predictions of P_t among all predictions conditioning on the indicated information set. The optimal extrapolative prediction $E(P_t \mid P_{t-1}, P_{t-2}, \ldots)$ in general differs numerically from P_t^* and, therefore,

$$E[P_t - E(P_t \mid Y_{t-1}, \ldots; P_{t-1} \ldots)]^2 \leq E[P_t - E(P_t \mid P_{t-1} \ldots)]^2, \qquad (2.18)$$

where the discrepancy is accounted for by the squared difference between the alternative predictions. Thus, rational expectations are necessarily more efficient (or at least as efficient) in a mean-square error sense.

Nerlove, Grether, and Carvallo (1979) present their view that the adaptive expectation model arbitrarily defines a coefficient of expectations; whereas, the rational expectations approach under the assumption of the unbiasedness of the expectations leads to a formation in which the coefficient of expectations is a function of parameters and exogenous information from the structural form of the model considered.

Wallis (1961) indicated, from the economic point of view, that rational expectations are more consistent with the underlying structure of economic behavior considered in the model studied; whereas, alternative models of expectations (cobweb, extrapolative, and adaptive) are not necessarily compatible with the economic behavior implied by the underlying economic structure.

Sinclair (1983) summarizes a rational expectations equilibrium which fulfills the following conditions:

(1) At least one relationship governing variables in the economic model is subject to random disturbances. This assumption distinguishes a rational expectations equilibrium from a perfect foresight equilibrium.

(2) Agents form expectations on the basis of all available information in conformity with the model itself. This

assumption stipulates that agents optimize their predictions of future events no less than in any other aspect of their behavior.

A rational expectations equilibrium must include stochastic elements. In most economic contexts, rational expectations equilibria are analyzed in models that take the random elements to be exogenous, like the weather.

Despite the superiority of the rational expectations model over the naive expectations model found by several authors, Lamm (1981) showed results indicating that neither model is superior to the other. He emphasized that the naive expectations result differs from the rational expectations marginally. Therefore, the full rationality, according to Lovell (1986), has a more demanding implication because the variables known to the forecaster must be uncorrelated with the forecast error. Adams (1986) stated that REH should be used even if it is not pure form.

Nelson (1975) concluded that even economists can understand the economic system as the hypothetical Rational Expectations Hypothesis has claimed, but they cannot predict with accuracy because of specification error and parameter estimation.

However, Ormerod (1983) suggested that the agent may be assumed to be rational in the sense of Rawls by using information currently available in an efficient manner. According to Rawls (1971), the rationality of a person's choice does not depend upon how much he knows, but upon how well he reasons from information he has, however incomplete.

According to Zijp (1993), price forecasting derived from the structural equation is the strong form of the Rational Expectations Hypothesis (REH). Because producers know at least the true structure of the model; however when producers optimize the information on which they base their decisions, Zijp describes this as the weak form of the REH.

2.2 Producers' Price Expectations: Empirically

Empirically, the relation or ratio between corn prices and hog prices is always an important factor in influencing hog production. Hog prices may be low, but this factor may be offset by a still lower corn price (Shepherd, 1958). It is the ratio between the two prices that determines whether corn will be fed to hogs and more hogs raised, or whether breeding hogs will be sold and the corn marketed as grain. Cycles in numbers and prices of hogs are perhaps set in motion by "shocks" from outside the hog enterprise, such as the weather's effect on the size of the corn crop (Brunk and Darrah, 1955). Corn prices change from year to year, and this variation in corn prices has made hog production seem, temporarily, very profitable for farmers and sometimes very unprofitable.

The relationship between the price of hogs and the price of corn is generally referred to as the hog-corn ratio (Fowler, 1957). Williams and Stout (1964) indicate that Harlow insists the hog-corn price ratio is an extremely reliable indicator of the direction of change in the number of sows farrowing. They explain that government price supports and storage programs for corn tended to stabilize corn prices by reducing effects of variations in corn production. As a result, hog prices assumed a more prominent role in determining hog production (Williams and Stout, 1964).

Meadows (1970) states that,

> Fluctuations in the price of hogs cause financial hardship for hog producers. When variations in the corn supply were identified as contributing to the instability in hog production, the government began to enact various acreage control and price support programs for corn. Most important of these was the Agricultural Adjustment Act of 1938. With some modifications, it remains in effect today. (p. 38)

However, Blosser (1965) emphasizes that the hog-corn ratio is a poorer indication of hog profits today than it was 40 years ago because corn has become less important. Ensminger and Parker (1984) insist that the hog-corn ratio still stimulates more breeding if there is cheap corn and high-priced hogs, because a high hog-corn ratio is likely to contribute to producer profit. However, Ensminger and Parker agreed with Blosser that the hog-corn ratio is declining in importance as an indicator of future hog production because there are fewer small operators; large operators hold hog numbers near full capacity, so they do not expand or contract with changes in hog prices; the hog business is capital-intensive, especially the modern slotted-floor confinement-type farrowing and finishing units; and nonfeed and fixed expenses are a larger part of cost than in earlier years.

Several investigators have studied historical hog production and found statistical evidence of cycles of three to four years in length. Therefore, there is an oscillating movement of output and price in the opposite direction in quarter t (or the same quarter), i.e., the increase in hog production causes a fall in price in the same quarter and a fall in hog production leads to a rise in price in the same quarter. Newberry and Stiglitz (1981, p. 105) mentioned that "if they (farmers) fail to appreciate the negative correlation between output and price, they will oversupply."

2.3 Hog Models

Many published studies have used lag structures to determine the hog supply response. Because of the differences in estimation procedures and mathematical forms of the statistical equations, the lengths of the biological lag in these modes range from two to three quarters to as long as five.

The price variables used in demand side equations usually are the price of barrows and gilts (or aggregate price of live hogs), retail price of pork, personal income, price of beef, (or quantity of beef), wages at the packer level and lagged hog price. Only one model used a time trend, and four models used dummy variables to cope with technological change and seasonal variation respectively.

Eleven models presented in this section offer interesting perspectives on methodological issues in live hog market models. Empirically, demand and supply remain the principal pillars for these analyses. But, there are radical econometric differences among these models. However, these models do not appear to reflect the current issues and the development of the Rational Expectations Hypothesis in Muth's sense. In addition, there is no broad discussion on how the Rational Expectations Hypothesis has been involved in the live hog market recently. Tables 2.1 and 2.2 summarize the demand and supply side of the various models and their differences. Details of the hog models are discussed in the Appendix.

2.4 Hog Model with Price Risk

Agricultural marketing is a risky business. One of the greatest risks in agricultural production and marketing is the risk of price change between

Table 2.1. Studies of the Hog Models: Supply Side.

Study	Estimation Procedure	Period of Study	Expectation Variable	Biological Lag	Dummy Variables
Leuthold and Hartman (1979)	Ordinary least squares (OLS), recursive system	1964-1976	None	Six months or two quarters	Yes
Leuthold and Hartman (1982)	OLS, recursive system	1971-1977	None	Study in very short run, there is no biological lag.	Yes
Dixon and Martin (1982)	OLS, one equation (random coefficient model)	1965-1979	None	The quantity supplied of hog depends on five-quarter lag of hog prices and feed prices. There is no biological time lag physically.	Yes
Brandt and Bessler (1983)	OLS, one equation	1971-1981	None	Implicitly, the equation shows biological lag two and three quarters, respectively.	None
Marsh (1984)	OLS, one equation	1971-1981	Yes Expected sow slaughter. Some sows that have farrowed in the beginning of a quarter and have had the pig weaned could be sold to all slaughter.	Two and three quarters. respectively.	None
Holt and Johnson (1983)	OLS, system of supply equation	1969-1985	Current and lagged hog price and feed cost, respectively.	One, two, and three quarters. respectively.	Yes

Table 2.1 (continued)

Study	Estimation Procedure	Period of Study	Expectation Variable	Biological Lag	Dummy Variables
McAulay (1978) in Canada	OLS for supply equation, 2SLS for demand equation, system of equation	1966-1979	None	Five quarters.	Yes
Heien (1975)	OLS, system of equation	1950-1969	Yes (Using distributed lag form price and feed cost.)	Nonet show biological lag.	None
Roy and Roberson (1989)	3SLS, system of equation	1979-1988	Yes (Using last previous growth rate as the proxy of the expected exogenous variables.)	Two quarters	None
Shonkwiler and Spreen (1982)	Dynamic regression technique, recursive system	1946-1979	None	Implicitly, one, two, three quarter lag.	None
Bessler (1984)	OLS, a vector auto regression five variable system	1958-1981	None	One quarter lag. Forecast error variance in the hog slaughter series is explained primarily by innovations in the hog slaughter and sow farrowing series at lags of one year or less.	None

Table 2.2. Studies of the Hog Model: Demand Side

Study	Demand Equation	Variable of Hog	Time Trend	Dummy Variable
Leuthold & Hartman (1979)	Yes	Average Price of Hog, Barrows and Gilts	None	Yes
Leuthold & Hartman (1982)	Yes	Wholesale price of hog pork production, and D_i	None	Yes
Dixon & Martin (1982)	None	None	None	None
Brandt & Bessler (1983)	Yes	Price Disposable Income, Sow Farrowing, Hog Corn meat availability, Broiler-Type chicks hatched, D_i	None	Yes
Marsh (1984)	None	None	None	None
Holt & Johnson (1983)	None	None	None	None
McAulay (1978) in Canada	Yes	Price of Live Hogs, Price of Beef, demand income.	None	Yes
Heien (1975)	None	None	None	None
Roy & Roberson (1989)	Yes	Price of live hog, retail price, live hogs, wages at packer level.	Yes	None
Shonkwiler & Spreen (1982)	None	None	None	None
Bessler (1984)	Yes	Price of live hog, lagged price, DPI, lag sow farrowing, Time trend	Yes	None

the time when plans are made or produce purchased and the time of final sale. The uncertainty of future prices applies to any particular year or season, as well as to secular or long-run price changes.

Hurt and Garcia (1982) considered that price risk is difficult to predict ex ante. There are two main reasons for that difficulty: (1) The risk response in sow farrowing and (2) the limited ability of hog futures market prices to predict subsequent spot prices. In their model, Hurt and Garcia defined price risk as the squared deviations of expected price and actual price. Price risk variables are the prices of hogs and corn, with the futures price of hogs and corn as the price expectations. They suggested that the specification using last quarter's price is the expected price in the risk definition.

Recent history provides evidence of price risk in feeder pig production. For 170 months from December 1974 (Qtr I is composed of December 1974, February 1975, and February 1975) to Janaury 1989, producers suffered losses in 108 of those months as shown in Figure 2.4. Therefore, these losses can cause them to be risk averse producers.

In firm-level models, risk aversion has been recognized as an important influence conditioning response. Empirical progress, however, has usually rested on measuring risk by the variance or standard deviation of revenues. Ensminger (1984) expressed this situation that producers cannot have excess profit and there is risk in the long run.

Producers perceive the tendency of prices to decline through time. They will take this trend into consideration to base their production plans. For example, Halter and Dean (1971) learned that when turkey prices declined sharply from 1950 to 1957, producers counted the downtrend as their subjective distribution. In the near future the high prices will not occur as of the early 1950s.

Shepherd (1963) considered that farmers do not respond immediately to a change in price, because the change in price might be temporary.

The question of using actual values or differences between these values has been unclear for a considerable time. Nevertheless, many empirical studies have used differences. DeLeeuw (1991) found that the change in expectations was a coincident indication of the level of output.

2.5 The Relationship Between the Efficient Market and the Rational Expectations Hypotheses or Model

Muth (1961) defined rational expectations in the following way:

> The essence of the hypothesis is that the way expectations are formed depends specifically on the structure of the relevant system described by economy. (p. 316)

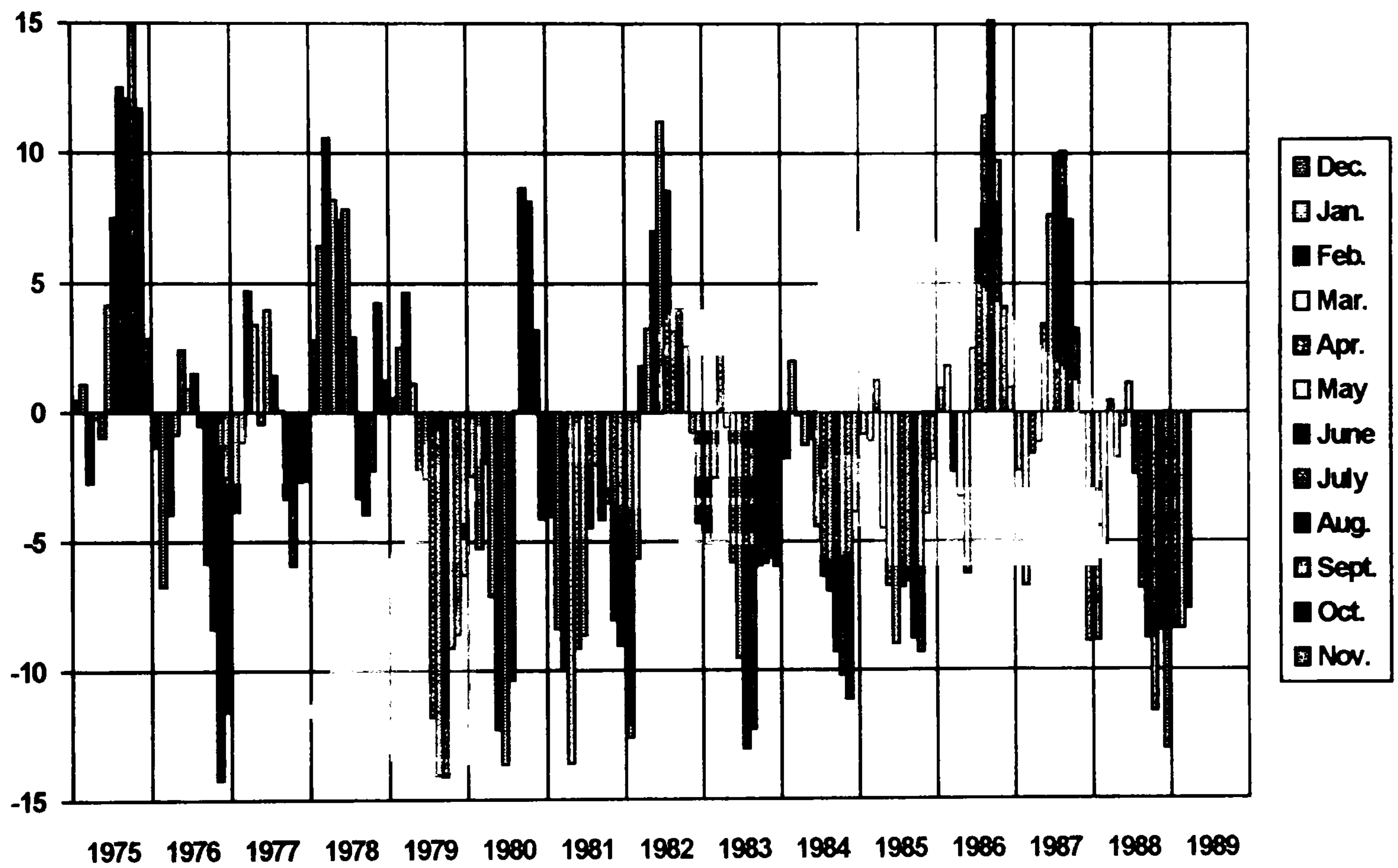


Figure 2.4. Monthly Net Margin per cwt for Feeder Pig Producers, Cornbelt, 1975-1989.

Source: Livestock and Meat Outlook and Situation, 1990.

Muth (1961) asserts that if market expectations were not moderately rational, there would be opportunities for economists and other market analysts to make profits from commodity speculation. Hirshleifer (1972) developed a general equilibrium model of the speculative process that leads to the conclusion that if all individuals shared the same beliefs, there would be no speculation.

Cox (1976) emphasized that when some traders do not have the most recent market information, the current market price will equal a linear combination of past prices plus a random error term; while with an increase in market information, the coefficients of past prices all decrease in absolute value and the variance of the price forecast error decreases.

Fama (1970) classified empirical tests of marketing efficiency into strong, semi-strong, and weak forms. He indicated that an efficient futures market should reflect all information about expected supply and demand. Such a market should provide an unbiased and efficient estimate of the actual price at contract maturity.

In the weak form, there is no relationship between previous futures prices and the current futures price. The two prices are independent over time. The value of historical information is already reflected in current prices. Thus, studying past futures prices is useless for predicting subsequent prices. In other words, the overall value of technical analysis (based on trends in price movement) is questionable. Weak form efficiency may be equivalent to rational expectations if an agent's information set is restricted to the past history of prices.

The semi-strong form holds that futures prices adjust immediately to new data. All public information is reflected in a futures prices.

In the strong form, futures prices reflect all information, public and private (insider). Here we have a perfect market. The assumption is that no group of investors has monopolistic access to information. Assuming this, no group can earn superior risk-adjusted returns.

Summarizing from Fama (1970), an asset market is said to be efficient if (1) prices fully and instantly reflect all available information and (2) no profit opportunities are left unexploited. Therefore, the efficient market hypothesis (EMH) is a joint hypothesis that agents form their expectation rationally on the basis of the current information set and arbitrage away any expected returns consistent with supernormal profits.

Fischer and Jordan (1983) reviewed the random walk theory that previous price changes or changes in the past price are useless in predicting future price changes.

Sprecher (1975) presented a summary of the random walk hypothesis (RWH). He notes that the RWH emerged from the empirical test of changes in bond prices from 1900 in France. The RWH states that the change in stock prices (or futures prices) from one period to the next is independent. The RWH can be represented as:

$$P^f_t = P^f_{t-1} + e_t, \qquad (2.19).$$

where

P^f_t = futures price of a commodity at time t,

P^f_{t-1} = futures price of a commodity at time (t-1), and

e_t = normally distributed error term with expectation of zero.

Since e_t is a normally distributed error term, knowing the price at time (t-1) will not provide any information about the change at time t. As a result, the history of futures price changes will not enable the investor to obtain an above-average return. A more frequently referenced process in the time series literature is a random walk with drift,

$$P^f_t = P^f_{t-1} + \delta + e_t, \qquad (2.20)$$

where δ is a deterministic trend constant. The random walk is recognized as a martingale (fair game model) and the random walk with drift is an example of a submartingale

$$E(P^f_t | P^f_0, \ldots, P^f_{t-1}) \geq P^f_{t-1}, \qquad (2.21)$$

where E is the expectation operator. With the independence assumption, early random walk theorists also made some rather restrictive assumptions about probability density functions of price changes. Subsequent empirical studies found that these conditions were not met. As a result, a less restrictive fair game model (FGM) was formulated, which did not require the assumptions about the underlying stochastic processes of futures prices.

Empirical tests of the efficiency of the futures market have generally taken three different forms. First, there are studies that have investigated historical price movement. Most of these studies were undertaken in connection with the RWH, but they have important implications for the more general FGM. These studies were generally concerned with determining whether price changes were independent (Fama, 1965; Niederhoffer and Osborne, 1966; Osborne, 1959). Second, with the development of the FGM, tests have been conducted to determine the speed of adjustment process to new information (Fama et al., 1969). Since the FGM postulates that the current futures prices fully reflect all current information, this raises the question of how quickly futures prices adjust to new information. Finally, studies have been conducted to determine the benefits that can be gained from inside information. The FGM states that current prices fully reflect all known information. Obviously, someone who has inside information would be expected to obtain an above-average return simply because this information is not reflected in the prices of stocks.

Lev (1974) explains the mean reverting process which supposes that P_t^f is a random variable whose expectations (i.e., mean value) remains constant over time. The behavior of P_t^f is described by the following process:

$$P_t^f = \mu + a_t \tag{2.22}$$

where

μ= the expected value of P_t^f and

a_t = a random disturbance term having a zero expected value, constant variance, and is serially independent.

The model implies that $E(P_t^f)$ is constant over time. In other words, average periodic P_t^f is expected to be stable over the long run at the level of μ. When $E(P_t^f)$ is constant over time, actual P_t^f will tend to revert to the mean; specifically, P_t^f that is in a given period higher than the mean will, on the average, be followed by lower P_t^f, and vice versa.

A more general and probably more intuitively appealing version of the mean reverting process is one in which the expectation is a deterministic (known) function of time. The behavior of this model can be described by

$$P_t^f = \mu_t + a_t \tag{2.23}$$

and the expected value $E(P_t^f)$ will equal to the mean μ_t. The expectation function, μ_t, may take various mathematical forms, such as linear or curvilinear. Both processes, the constant expectation and the time-changing expectation, are thus characterized by negative first-order serial correlation which reflects the mean-reverting nature of the processes.

Fama (1970) emphasizes that Muth's (1961) paper provided a theoretical foundation for studies in price behavior in speculative markets. These efforts led to the theory of efficient markets. The Muth Rational Expectation Hypothesis implies that the economy makes full use of information. If expectations were not formed rationally, economists, with knowledge of economic theory, would be able to make abnormal profits by speculating.

Hamlin (1983) asserts that economic agents' subjective probability distributions are identical to the mathematical probability distribution conditional on the true model of the economy. In statistical notation, the Rational Expectations Hypothesis takes the form of

$$E(P_t | I_{t-1}) = {}_{t-1}P_t, \tag{2.24}$$

where

${}_{t-1}P_t$ = the subjective expected value of hog price and

$E(P_t | I_{t-1})$ = the conditional expected value of P_t conditional on the set of total information I_{t-1} available at time (t-1).

$E(P_t|I_{t-1})$ is an unbiased predictor of P_t. One of the important applications of rational expectations is the commodity futures market. In the context of commodity futures, market efficiency implies that all the information relevant to predict future spot prices of a commodity is fully reflected at the time of prediction in the commodity future prices.

2.6 Rational Expectations and Futures Price as an Unbiased Predictor of Subsequent Spot Price

Futures markets are described as having two important social functions. First, they facilitate the transfer of price risk. Risk transfer refers to hedgers using futures contracts to shift price risk to others. Second, they provide forecasts of commodity prices which we call forward pricing of a commodity.

French (1986) states that,

> . . . [t]he evidence that futures markets transfer price risk is irrefutable. However, there is some debate about the markets forecasting ability. (p. 39)

Theoretically, the futures price and the rational expectation price should produce an unbiased estimate of the subsequent spot price, since futures and rational expectations prices are the same because each uses all information available. The hypothesis that futures prices are the best unbiased forecasts of future spot prices is often presented in the economic and financial analysis of futures markets. In economic analysis, the hypothesis often appears under the heading of rational expectations, while in the finance literature, the term "market efficiency" is employed. Still, there is no definitive agreement from prior studies as to whether rational expectations price or futures price is an unbiased forecast of subsequent spot price because of the differences in the nature of the commodities analyzed and the times of the different studies. The following research is presented to clarify the problem concerning pricing efficiency.

Miller and Kenyon (1979) contend that the hog cycle is explained by backward-looking expectations. If futures prices exhibit rational price formation, as suggested by Gray (1972) and supported by Gardner (1976), hog producers' utilization of the futures market would have the potential to dampen the production cycle. Stein (1991a) concludes that there is a growing body of evidence which suggests that, in the absence of futures markets, cobweb cycles persist for long periods of time. When futures markets are introduced in commodities, these markets behave in a manner much more consistent with RE.

Hayes and Schmitz (1987) examined the existence of hog cycles produced by a form of cobweb behavior. From 1902 to 1941 there was a cobweb cycle. Countercyclical production strategies would have been profitable. The hog cycle persisted for decades. The questions are why the cycle lasted so long and why it became insignificant when futures trading was introduced. Why did the cobweb response almost disappear when futures trading developed?

In the past, futures markets have contributed to marketing efficiency through reducing risk of price change, increasing availability of capital and loan terms to the industry, and developing a market structure that fostered movement of product from the farm to the user. In this case, the contribution of futures trading to market efficiency is primarily a result of the contribution of hedging to market efficiency. These same people recognize the need and value of sufficient speculators to make the hedging market work efficiently. However, there is another group concerned with futures trading which maintains that such a market would contribute to market efficiency even if there were no hedging. Their argument is based on the belief that futures markets determine competitive spot prices, since the number of buyers and sellers in such a market is so great and that the other criteria for a competitive market are available.

At the maturity date of a futures contract, the futures price must be very close to the corresponding price in the spot market at the delivery point. If not, it will be profitable to make or take delivery of the product (depending upon the nature of the cash-futures price relationship); and this possibility will force the two markets together. This tendency for spot and futures prices to be together at contract maturity means that a price change in the spot market can be offset by an opposite position in the futures market.

Kolb (1991) shows the relationship between futures prices and the subsequent spot price (see Figure 2.5). Case I, normal backwardation, can happen if the expectation about the future spot price is correct and hedgers are net short, then the futures price must lie below the expected futures spot price. Therefore, the futures prices can be expected to rise over the life of a contract. In Case II, contango, hedgers are net long. Then the futures price would lie above the subsequent spot price and the price of the futures contract would fall over its life. Assume that market participants correctly assess the subsequent spot price, so that the expected future spot price turns out to be the actual spot price at the maturity of the futures contract. Case III is where the futures price equals the expected future spot price; then the futures price will be on the dotted line.

Samuelson (1965) concludes that spot prices should have systematic behavior while the movement of futures prices in a perfect market is essentially a random walk. Kamara (1984) reviews studies on the volatility of futures prices and the results suggest that there are two theories of why and how the volatility of futures prices change over a contract's life. Samuelson (1965) postulated the time to maturity hypothesis, arguing that

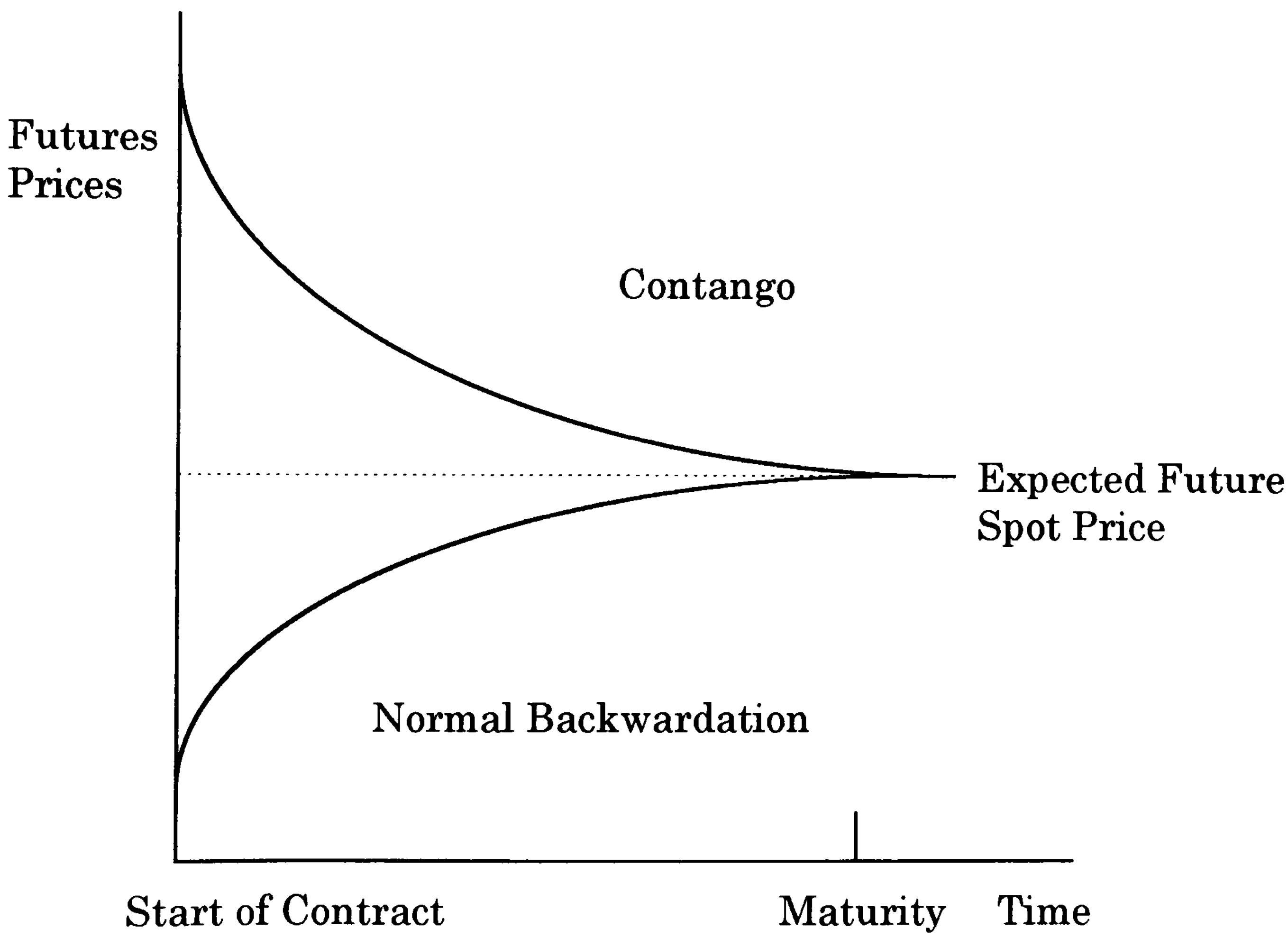


Figure 2.5. Patterns of Futures Prices.

Source: Kolb, R.W. Understanding Futures Markets. Third edition (1991), p. 122.

the volatility of futures prices increases as the maturity date approaches. The empirical evidence shows that the hypothesis holds for some futures markets, but not for others. The second hypothesis, the state variable hypothesis, postulates that the variance of futures prices may rise or fall over the contract's life depending on the distribution of the underlying state variable. The state variable hypothesis is stated most explicitly in Anderson and Danthine (1983), who argued that changes in the volatility of futures prices depends on the pattern of information flow into the market, with futures prices being more volatile in periods in which a large amount of uncertainty is resolved and relatively stable in periods in which little information flows into the market.

Larson (1983) indicates that Just and Rausser's (1981) findings are consistent with a growing list of works describing the consistency between futures markets and Muth's (1961) Rational Expectations Hypothesis [see Danthine (1978) and Gardner (1976)].

The three issues of hedging effectiveness, market efficiency, and price discovery are all connected due to the central role of expected price. Price changes in futures markets lead price changes in spot markets more often than the reverse. Garbade and Silber (1982) find that, in general, futures markets dominate spot markets. Evidence suggests that the spot markets for the commodities, wheat, corn, and oranges, with about 75% of new information incorporated first in futures prices and then following to spot prices.

Miller and Kenyon (1979) find causality running from live hog futures prices to spot hog prices. They interpret that result as providing evidence that the live hog futures market is important in the discovery of spot prices on a day-to-day basis. Hudson (1987) reviews the available empirical evidence on the lead-lag relationship between spot and futures prices and suggests that the spot and futures markets actually work together in discovering the market clearing price.

Telser (1967) mentions that futures prices are unbiased predictors of subsequent spot prices. Some economists have explored the accuracy with which futures trading can establish forward prices using a variety of empirical methods (discussed below). The general conclusion is that the accuracy of forward pricing may depend on whether the commodity is storable.

Kofi (1973) presents the benefits of futures markets by recognizing that:

> . . . the degree to which futures markets provide forward prices is more pronounced in the planting season because at this time future supplies are a matter of estimate, and the hedging use of the market is minimal. Thus, the "forecasts" (futures prices) of the harvest time cash prices in the planting season may be used as indicators of how well the futures market is able to predict future market conditions. (p. 585)

Leuthold and Hartman (1979) use an econometric forecasting model to evaluate futures market forward pricing. They found that the model provided more accurate forecasts of subsequent prices than the futures market, implying that the live hog futures market was not performing efficiently, presumably because of the market's inability to reflect fully all the information. Just and Rausser (1981) confirm Leuthold and Hartman's result that, for nonstorable commodities, some of the econometric forecasts seem to be preferable for livestock commodities. Just and Rausser suggested further that it is quite possible for smaller econometric models designed specifically for forecasting prices to outperform the large scale models examined in their paper.

What other forecast might be more accurate? For at least 60 years, economists have been concerned with how people forecast economic events. Many economists believe that people make the best economic forecast they can, given the information available to them at that time. Therefore, the ways people form expectations should give the different results. Pasour (1988) suggests that in order to prove market inefficiency in the Leuthold and Hartman approach, it is necessary to find only one case in which some other model predicts better.

Martin and Garcia (1981) find that live cattle futures are inadequate in forecasting spot prices. On the other hand, they find that live hog futures perform relatively well in forecasting spot prices during stable economic conditions, but poorly during unstable conditions.

Leuthold and Hartman (1980) use a semi-strong form test of market efficiency to compare the performance of futures markets with econometric models in forecasting subsequent spot prices of cattle, hogs, and pork bellies. Based on empirical results, they concluded that, at times, futures markets do not appear to utilize or correctly use all available information to reflect prices accurately in the future.

Just and Rausser (1981) suggest that forecasts based on futures prices are not excelled by other forecasting techniques. Although there is some degree of accuracy in the futures market as a forecasting tool of several agricultural commodities, futures forecasts have been compared to other techniques and have not been found inferior. The commodity price forecasts from the futures market are generally more accurate than from large-scale econometric models. According to Just and Rausser (1981), the econometric models for hogs provide superior forecasts only in a four-quarter ahead time horizon.

Kolb (1991) point out the inferiority of the forecasts from the futures market because most of the time futures prices fluctuate radically. Therefore, futures prices provide an inaccurate forecast of the underlying commodity spot price at the time of delivery. As a result, the large size of the forecast errors from the futures markets limits the reliability of the forecasts.

Cooley and DeCanio (1976) tested a Rational Expectations Hypothesis for American agriculture during the populist period, 1867-1914. Using a varying parameter estimation method, it is possible to trace changes in the supply response parameter over time and to compare these parameter variations with the variation implied by a model of rational price expectations. Cooley and DeCanio showed that changes in farmers' price expectations were indeed consistent with the theory of rational expectations.

2.7 Estimation Technique for Rational Expectations Model

Begg (1982) explained that the full information estimation method (FI) is more efficient than the limited information estimation method (LI). However, the LI method is superior to the FI method for two reasons: (1) the LI method is much easier to implement and (2) the FI method can spread the misspecification throughout the whole structural equation. But the LI method confines the inconsistent estimates to only the misspecified equation.

According to Wallis (1980), the rational expectations model may theoretically be estimated efficiently by full-information, maximum likelihood (FIML). However, Sargent (1978) considers that FIML has a number of drawbacks, such as FIML is costly and produces the presence of multiple maxima of the likelihood function. Powers and Ullah (1987) explain further that, because of those drawbacks, applied researchers in macroeconomics have had recourse to LI.

2.7.1 Single-Equation Estimation Techniques

Two single-equation estimation techniques will be considered. First, the substitution method due to Sargent (1973, 1978) and Wallis (1980); second, the errors-in-variables estimator due to McCallum (1976) and Wicken (1982).

To explain the two techniques, consider the model in the matrix forms as:

$$AX_t + \Gamma Y_t + BE_{t-1}X_t = U_t, \tag{2.25}$$

where

X_t = m x 1 vector of endogenous variables at time t,

Y_t = g x 1 vector of exogenous variables at time t,

$E_{t-1}X_t$ = the rational expectation of X_t formed at time t-1,

U_t = m x 1 vector of normally distributed white noise random disturbances at time t, and

A, Γ, and B = matrices of unknown parameters of order m x m, m x g, and m x m, respectively.

We assume for simplicity that the exogenous variable Y_t is generated by the following process:

$$Y_t = C(L)Y_t + e_t, \tag{2.26}$$

where C(L) is a pth-order matrix polynomial in the lag operation L; that is, $LY_t = Y_{t-1}$, etc., and e_t is assumed to be a g x 1 vector of white noise random disturbances independent of U_t.

By taking expectation (E_{t-1}) on the information set I_{t-1}, equation (2.25)

$$AE_{t-1}X_t + \Gamma E_{t-1}Y_t + BE_{t-1}X_t = 0. \tag{2.27}$$

$$\begin{aligned} (A+B)E_{t-1}X_t + \Gamma E_{t-1}Y_t &= 0 \\ E_{t-1}X_t = \frac{-\Gamma E_{t-1}Y_t}{(A+B)} &= (A+B)^{-1}\Gamma E_{t-1}\, Y_t. \end{aligned} \tag{2.28}$$

The rational expectations solution may then be written in the matrix form as:

$$E_{t-1}X_t = -(A-B)^{-1}\Gamma\sum_{i=1}^{p} C_i Y_{t-1}.$$

The process of deriving the conditional expectation is the same as the solution for the rational expectations price which was mentioned above. But, in this case, all the variables are being denoted in matrix form. Then, substituting $E_{t-1}X_t$ into equation (2.25) yields,

$$AX_t + \Gamma Y_t - (A-B)^{-1}\Gamma\sum_{i=1}^{p} C_i Y_{t-1} = u_t. \tag{2.29}$$

Theoretically, this model can be estimated by FIML (Wallis, 1980).

2.7.2 Substitution Method

The substitution method may alternatively be written in terms of the forecasting equation

$$X_t = -(A - B)^{-1}\Gamma\sum_{i=1}^{p} C_i Y_{t-1} + V_t, \tag{2.30}$$

where V_t is the vector of forecast errors, $X_t - E_{t-1}X_t$. By the Rational Expectations Hypothesis, this vector is orthogonal to the information set at time (t-1), that is, $E(V_t | I_t) = 0$.

Consider a single equation from equation (2.30). Assume that there is only one rational expectations variable appearing in the single equation:

$$x_t = [E_{t-1}s_t : S_t]\delta + u_t, \tag{2.31}$$

where

x_t = a scalar endogenous variable,

$E_{t-1}s_t$ = the rational expectation of an endogenous variable,

S_t = a row vector containing k endogenous variables and h-k-1 exogenous variables,

δ = an h x 1 vector of unknown coefficients, and

u_t = a normally distributed white noise random disturbance, where u_t is i.i.d.(o, δ^2).

To get a consistent estimate of the rational expectation $E_{t-1}s_t$ is replaced by small s_t by regressing s_t on ρ lagged values of all the exogenous variables in the model (2.30). The single equation can be estimated by two-stage least squares (2SLS) or instrument variables (IV) treating s_t as a predetermined variable. The instrument variable in the substitution method is $\hat{s}_t$.

2.7.3 Errors in Variables Method

The errors in variables approach to estimation in the rational expectations context (due to McCallum, 1976) begins by substituting the realized value, ss_t for the rational expectations variable, $E_{t-1}s_t$, yielding

$$x_t = [E_{t-1}s_t : S_t]\delta + u_t - \delta_1 n_t = Q\delta + v_t, \tag{2.32}$$

where δ_1 is the first element of δ and $n_t = s_t - E_{t-1}s_t$ is the forecast error which, by the Rational Expectations Hypothesis, is orthogonal to information set I_t. The v_t is the composite of errors $(u_t - \delta_1 n_t)$. The second stage in the errors in variables estimation procedure is to estimate

$$X_t = Q_t\delta + V_t \tag{2.33}$$

by using appropriately chosen instrument variables. The instrument variable in the errors in variable method is s_t, which is composed of lagged endogenous and exogenous variables or perfectly predictable exogenous variables.

McCallum (1976) indicates that substituting ex post realizations for the expected variables introduces an error in variables problem. McCallum proposes the use of instruments not only for the endogenous variables, but also for the exogenous variables appearing in the equation.

The problem of autocorrelation is encountered during estimation. Residual autocorrelation cannot exist in a rational expectations model for a one-period forecasting horizon, since systematic information should be incorporated into the conditional expectations in order for them to be rational.

2.8 Test of Rational Expectations Hypothesis

Test of rational expectations are usually tests of restrictions. Thus, the truth of rational expectations can be tested by the validity of those constraints.

2.8.1 Unbiasedness Test (or Pricing Efficiency Test)

The expectation should be an unbiased prediction of the variable. That is, a regression of the form:

$$P_t = a_0 + b_0 P^e_t + u_t \tag{2.34}$$

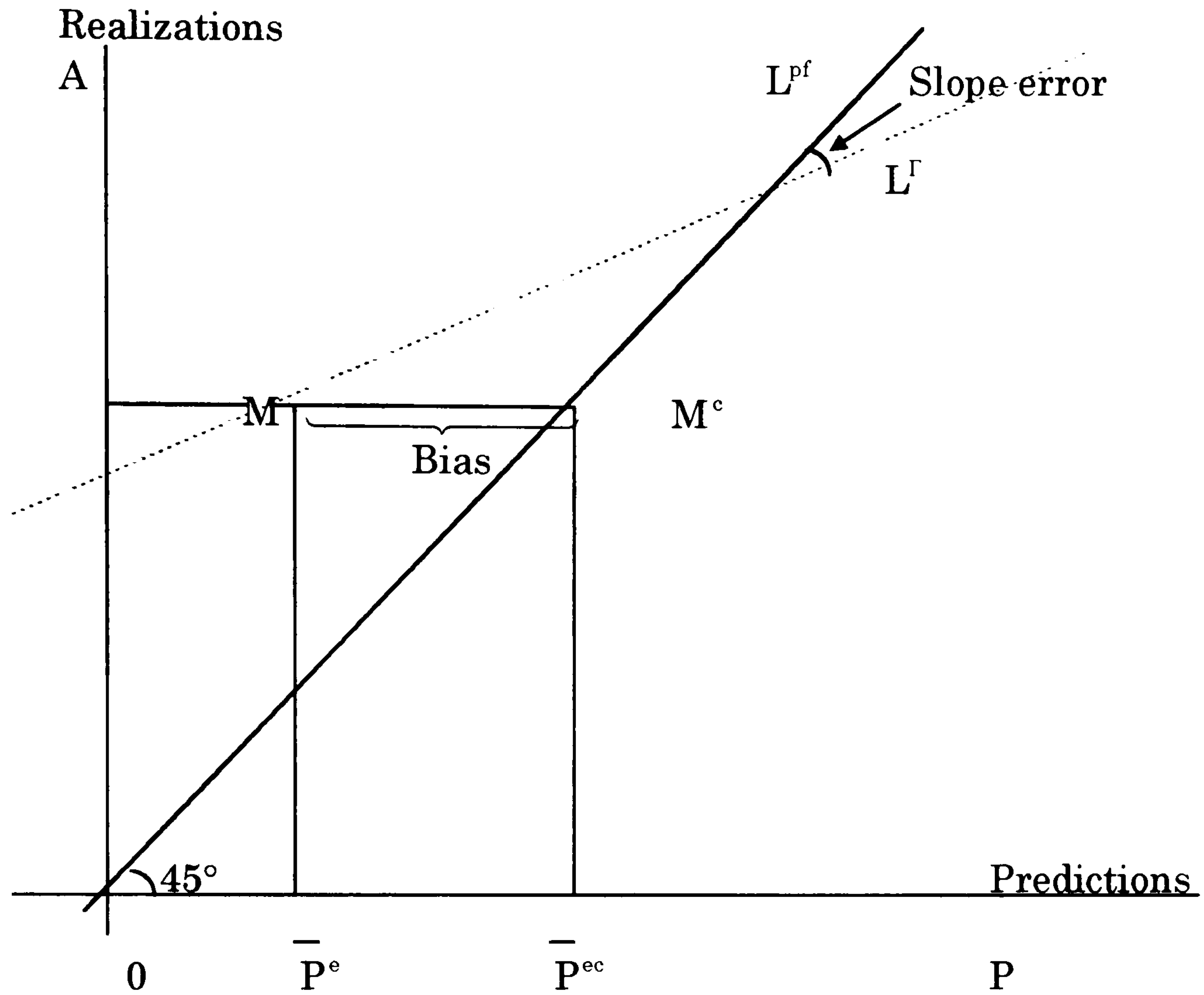
where

P_t = actual price of hogs at time t,

P_t^e = predicted price of hogs at time t-1, and

u_t = the forecast error.

The line denoted L^{pf} in Figure 2.6 is the line of perfect forecasts. The unbiased hypothesis states that the parameter a_0 should be zero, the value of parameter b_0 should be one, and $E(u_t) = 0$. Bias indicates that the mean of the actual series of hog price $\overline{P}$ is not equal to the mean value of the predicted series $\overline{P}^e$; therefore, the ordered pair $(\overline{P}^e, \overline{P})$ will not be on the L^{pf} line. If $a_0 = 0$ and $b_0 = 1$, the actual and forecast values will differ only by random error (u_t). Moreover, the error would equal zero, on the average, over long periods of time. We can use the standard F test to test the Rational Expectations Hypothesis. In Figure 2.6, the actual values of a commodity price (P_t) were plotted against the values that had been predicted (P_t^e). If the forecasts were perfect, that is, if the forecast errors at each point in time were zero, then the L^{pf} line would have an intercept of zero and a slope of one. The first criterion is said to define the unbiasedness property of the test. This unbiasedness property of the test will be pricing efficiency test if futures price is the regressor. There is a strong test of the Rational Expectations Hypothesis (REH), however, based on what is known as the efficiency property of the hypothesis.



where

P^{t} = actual price,

P^{e} = predicted price,

L^{pf} = line of perfect forecasts,

L^{r} = regression line,

$\overline{P}^{e}$ = mean prediction,

$\overline{P}^{ec}$ = mean corrected prediction,

P = mean realization,

M = mean point, and

M^{c} = corrected mean point

Figure 2.6. The Prediction-Realization Diagram.

Source: Jacob Mincer and Victor Zarnowitz, <u>Economic Forecasts and Expectations</u> (1969), p. 7.

2.8.2 Trading Rule Strategy

What justification do researchers use to test whether the futures market is efficient? If futures prices accurately reflect all information, then it follows that people should not be able to exploit existing information to earn abnormally large profits from speculating. In particular, if the futures market is efficient, then it should be difficult to make lots of money by "buying low" and "selling high." An alternative approach to the testing of the Efficient Market Hypothesis (EMH) is the construction of profitable trading rules. The forecasting method's ability to generate profit must be considered. Any regression which rejects the EMH implies a trading rule which results in profitable returns with zero transaction charges; therefore, the regression approach to testing may be seen as an efficient method for generating such a trading rule approach.

2.8.3 Cointegration Test

Elam and Dixon (1988) have criticized the use of pricing efficiency tests based on equation (2.34), noting that (1) estimates of a_0 typically become large and estimates of b_0 become smaller as the time to maturity of a futures contract increases and (2) there is inherent bias in the OLS estimates of a_0 and b_0 due to the presence of a lagged dependent variable. The authors present Monte Carlo evidence to argue that the customary F test of the joint hypothesis $a_0 = 0$ and $b_0 = 1$ is not valid, concluding that a new test is needed.

If both the dependent variable and independent variable series are unit roots, and resulted in the occurrence of the nonstationary series. To use the joint F-test, the first difference of both series are necessary in order not to have a spurious regression. However, there were many controversies among the researchers about the pricing efficiency in the futures market depending on whether the goods are storable or nonstorable.

Another method of testing of pricing inefficiency is the Cointegration test. Before testing with the Cointegration test, both series, dependent and independent variables, must be nonstationary (unit roots).

Dickey (1991) explained the meaning of the cointegration as

> one or more linear combinations of these variables is stationary even though individually they are not. If these variables are cointegrated, they cannot move too far away from each other. (p. 58)

The cointegration, for the same commodity, between the subsequent spot price and the futures price is a necessary condition for market efficiency. That is, the futures price should be an unbiased prediction of the subsequent spot price on average. If the subsequent spot price and futures price are not cointegrated, then these two prices tend to deviate apart without bound. It follows that the futures price has little predictive power about the movement of the subsequent spot price. This is not consistent with the market efficiency analysis (Lai and Lai, 1991).

2.8.4 Weak Information Efficiency

The Weak Rationality forecast must be unbiased and must not be rejected by the test of weak informational efficiency. Weak Informational Efficiency or Weak Orthogonality test determine whether the forecast error is uncorrelated with past values of the predicted variable.

Attfield et al. (1985) described that,

> If expectations of a variable are rational, they are formed in accordance with the process determining that variable and therefore they will depend upon that same set of past variables. This property of rational expectations is known as the efficiency property.(p. 107)

Under the rational expectations hypothesis, the forecast error $(P_t - P_t^e)$ is independent of all lagged information, in this case, lagged prices. Suppose we have:

$$P_t = P_0 + \beta_1 P_{t-1} + \beta_2 P_{t-2} + \ \dots \ + \beta_k P_{t-k} + U_{1,t}, \tag{2.35}$$

where

$\beta_i s$ = the coefficients to be estimated on each variable and

U_{1t} = a random error.

Since we are assumed to have a direct observation on $E_{t-1}P_t$, we can carry out a regression of $E_{t-1}P_t$ on exactly the same variables as those on the right hand side of equation (2.36).

$$E_{t-1}P_t = \gamma_0 + \gamma_1 P_{t-1} + \gamma_2 P_{t-2} + \ldots + \gamma_k P_{t-k} + U_{2,t}. \tag{2.36}$$

From equation (2.9) and equation (2.10), we can test the rational expectation hypothesis by testing the joint null hypothesis that $\beta_i \gamma_i = 0$ for all i in the following regression,

$$\begin{aligned} P_t - E_{t-1}P_t = \beta_0 - \gamma_0(\beta_1 - \gamma_1)P_{t-1} + (\beta_2 - \gamma_2)P_{t-2} + \ldots \\ + (\beta_k - \gamma_k)P_{t-k} + U_{1,t} - U_{2,t}. \end{aligned} \tag{2.37}$$

If the Rational Expectations Hypothesis is correct, we should find that $\beta_i = \gamma_i$. It then becomes obvious that the prediction error, $P_t - E_{t-1}P_t$, will not depend on any lagged values of the actual price. Rejection of this null hypothesis would imply a rejection of the Rational Expectations Hypothesis. Putting it another way, under rational expectations the forecast error $P_t - E_{t-1}P_t$, is independent of all lagged information; in this case, lagged prices (orthogonality property).

2.8.5 Sufficient Rationality

In order to be sufficient rationality, the forecast must be weakly rational, and must pass a more demanding test of sufficient orthogonality, namely, that the forecast error be uncorrelated with any variable at the time of prediction. For example, first run a regression where the forecast error is a dependent variable and the futures price $P^{f,t}_{t-4}$, cold storage (COT) protein (Pro) cost, population (Pop), and sow farrowing (SF) are independent variables. Second, compare between F computed and F critical values to test if the forecast error is correlated with the information available at the time of the prediction.

In summary, the naive cobweb, extrapolative expectations, and adaptive expectations have a common trait. They are basically arbitrary. These expectations depend on a previous price. The extrapolative expectation is based solely on the information contained in the actual values of the preceding price for two periods. An adaptive expectation, on the other hand, is based on the entire past history of the price series. The three expectations mentioned are inappropriate for forming reasonable expectations. They imply implausible conduct. As a result, Muth (1961) has developed an economic analysis about the formation of expectations, i.e., that economic agents do the best they can with what they have.

But, there are two reasons why an expectation may fail to be rational. First, people are unaware of available relevant information. Second, there is the forecast error of exogenous variables.

In the literature, there were materials concerning the development in forming price expectations such as using hog-corn price ratios and live hog prices at the time of decision making. The literature also contained materials that discussed whether the producers' expectations are consistent with the Rational Expectations Hypothesis. Some researchers consider futures as an unbiased estimation of a subsequent spot price. Moreover, they consider that futures price is a Rational Expectations price. Some researchers tried to include price risks and corn into the live hog model.

According to Muth, the price expectations is derived from the reduced form of the structural model. Then, the price expectations are inserted into the supply equation. Then, solving the predicted price from the structural equation again. Either the Limit Information System (LIS) or Full Information System (FIS) can be used to estimate the predicted price. However, there is a major drawback in LIS as well as FIS. The LIS method causes simultaneity bias, while the FIS causes specification bias. To test the Rational Expectations for the predicted price, the test of rationality (i.e., unbiasedness, weak information efficiency, sufficient rationality, and cointegration) must be performed successively.

CHAPTER III

CONCEPTUAL FRAMEWORK

This study is made up of all those combinations among pricing efficiency and optimal allocation of resources, structure of the hog supply, fundamental market model, producers' expectations, and the relationship between Rational Expectations Hypothesis and efficient market hypothesis.

3.1 Pricing Efficiency and Optimal Allocation of Resources

For simplicity, the producer will be restricted to one output, that is live hog, Q, with its technical production conditions contained in the production function $Q = F(X_i), i = 1, \ldots, n$. Consideration will be restricted to the effective region of the production function where all marginal productivities, $\frac{\partial F}{\partial X_i} = F_i$, are positive. Factor prices are denoted as P_i with the price of the output being P. The total cost is defined as $C = \sum P_i X_i, = 1, \ldots, n$, and the marginal cost is equal to $\frac{\partial C}{\partial X} = C'(Q)$.

The objective of the firm is to maximize its profit (π) subject to the constraints imposed by the hog producers' production function. This yields the Lagrangian expression:

$$L = PQ - \sum P_i X_i + \lambda\{Q - F(X_i)\}, \qquad i{=}i,\ldots,n.$$

The first-order or necessary conditions for the maximization are that the n + 2 equations

$$\frac{\partial L}{\partial Q} = P + \lambda = 0 \qquad (1)$$

$$\frac{\partial L}{\partial X_i} = -P_i - \lambda \frac{\partial F}{\partial X_i} = 0 \qquad (2)$$

$$\vdots$$

$$\frac{\partial L}{\partial X_n} = -P_n - \lambda \frac{\partial F}{\partial X_n} = 0 \qquad (n+1)$$

$$\frac{\partial L}{\partial \lambda} = Q - F(X_i) = 0. \qquad (n+2)$$

It is noted that at equilibrium

$$\frac{F_1}{P_1} = \frac{F_2}{P_2} = \ . \ . \ . \ \frac{F_n}{P_n}$$

so that the total expenditure is to be allocated among the different factors such that their marginal productivities per dollar's worth are all equal to each other.

Since $\frac{F_i}{P_i}$ are the same as $\frac{1}{MC_Q}$, then

$$\frac{F_1}{P_1} = \frac{F_2}{P_2} = \ . \ . \ . \ = \frac{F_n}{P_n} = \frac{1}{MC_Q}\,.$$

From equation (1), $P = -\lambda$, then $P_i + PF_i = 0$.

Therefore, $$\frac{F_i}{P_i} = P\,.$$

Thus, $$\frac{F_1}{P_1} = \frac{F_2}{P_2} = \ . \ . \ . \ = \frac{F_n}{P_n} = \frac{1}{MC_Q} = \frac{1}{P}\,.$$

When several variable resources are used by the firm, two problems are solved simultaneously by the firm in the process of maximizing its profits. It must use resources in the correct (least-cost) combination and it must use the absolute amounts necessary to produce that quantity of product which maximizes profits. In other words, producers seek to maximize their profit and are pushed by the profit motive to combine productive resources in the most efficient way to produce hogs that the packers can buy.

In general, the existence of a futures market increases the information available to all producers. Hence, hog producers can use the futures price to substitute for the expected spot price. If the futures prices are an unbiased estimate of the spot prices expected to emerge in the future, then the situation is called “pricing efficiency.” The profit maximization condition for hog producers using futures price as a proxy for subsequent spot price can then be as follows:

$$\frac{F_1}{P_1} = \frac{F_2}{P_2} = \ . \ . \ . = \frac{1}{MC_Q} = \frac{1}{P^{f,t}_{t-4}}$$

Since futures price information is free, hog producers can use the futures price to plan their production if there is pricing efficiency in the hog market. Therefore, pricing efficiency leads to efficient allocation of resources in the spot market. The economic benefits of having more accurate prices are well known.

3.2 Structure of Hog Supply

The leading hog markets of the United States are located in or near the Corn Belt, the area of greatest hog population. Approximately two-thirds of U.S. total hogs are produced in Iowa, Illinois, Minnesota, Indiana, Nebraska, and Missouri. Iowa is the major state with over 25% of the nation's total production (Figure 3.1). The diagram in Figure 3.2 shows the distribution of hogs from farmers through the channels for slaughter hogs. In 1980, most hogs and pigs were sold through the following channels: (1) direct, country dealers, etc. (76.6%); (2) terminal markets (also referred to as terminals, central markets, public stockyards, and public markets) (13.3%); and (3) auctions (9.1%) Spinelli and Duewer (1991) indicate that there were more than 1,100 plants slaughtering hogs in the United States in 1989;

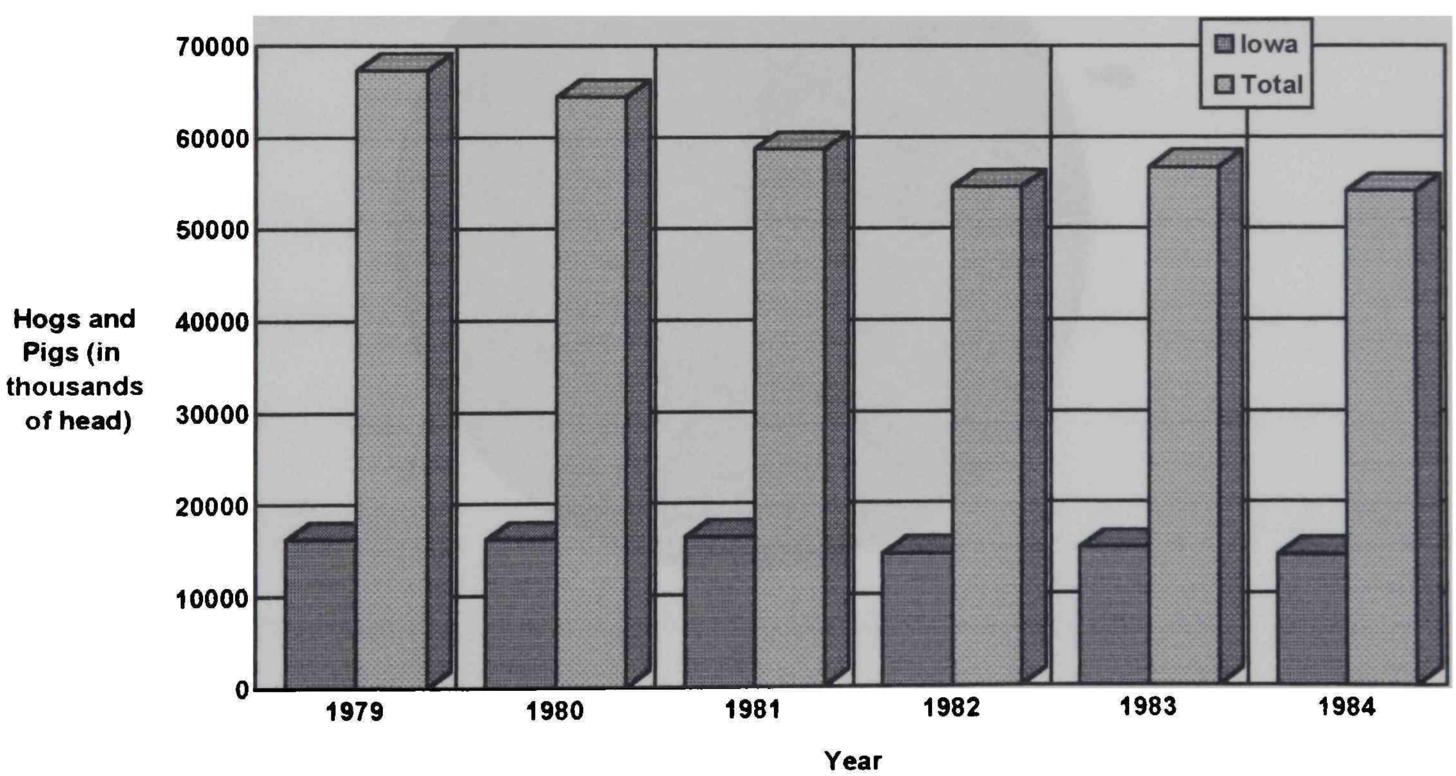


Figure 3.1. Hogs and Pigs on U.S. Farms on December 1 (in thousands of head).

Source: USDA, Crop Reporting Board.

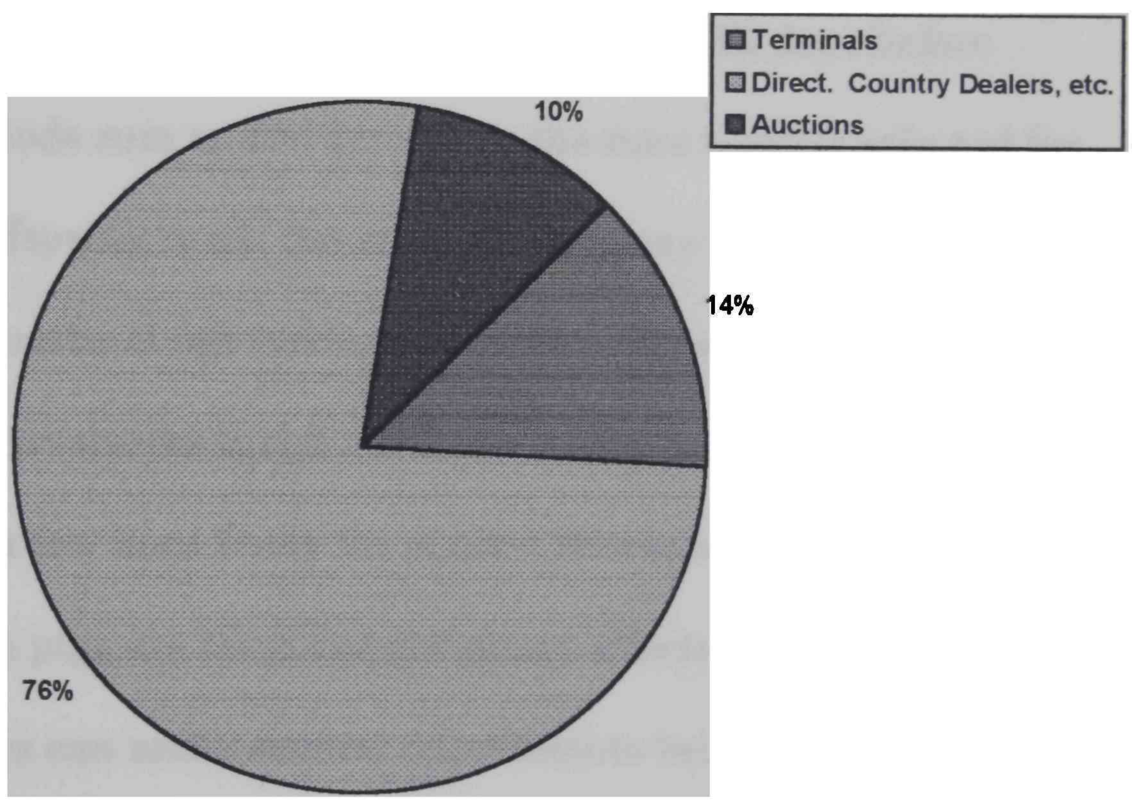


Figure 3.2. U.S. Market Channels for Slaughter Hogs, 1980.

Source: Based on information from Packers and Stockyard Resume, USDA, Vol.19, No. 5, 1982, p. 10, Table 3.

however, 33 plants accounted for 76% of the total U.S. hog slaughter and 24 of these plants each slaughtered more than 1.5 million hogs per year.

The actual production time for a market hog, from breeding to slaughter, is around nine months. The gestation period for hogs is approximately four months; that is, farrowing occurs approximately four months after breeding. Gilts reach both sexual maturity and slaughterweight at about six months of age. At six months of age, gilts can either be withheld from slaughter and added to the supply of breeding sows or slaughtered. A gilt selected for breeding may be held 42 days before breeding. These periods sum to 336 days from the time a gilt is selected for breeding until her offspring reach the market. Barrows are also fed to approximately six months of age before slaughter. Figure 3.3 shows the hog biological lag. Some producers breed a few sows each month of the year. In this way, they have a few hogs ready for market throughout the year.

The time when pigs are farrowed definitely affects the time of marketing. Producers can make several adjustments between farrowing and marketing which will permit earlier or delayed marketing. With the marketing date for finished hogs depending upon breeding and feeding programs, many farms combine the one- and two-litter systems to provide three farrowings a year. Sows are bred to produce two litters per year and gilts to produce one litter some time between the sow farrowings.

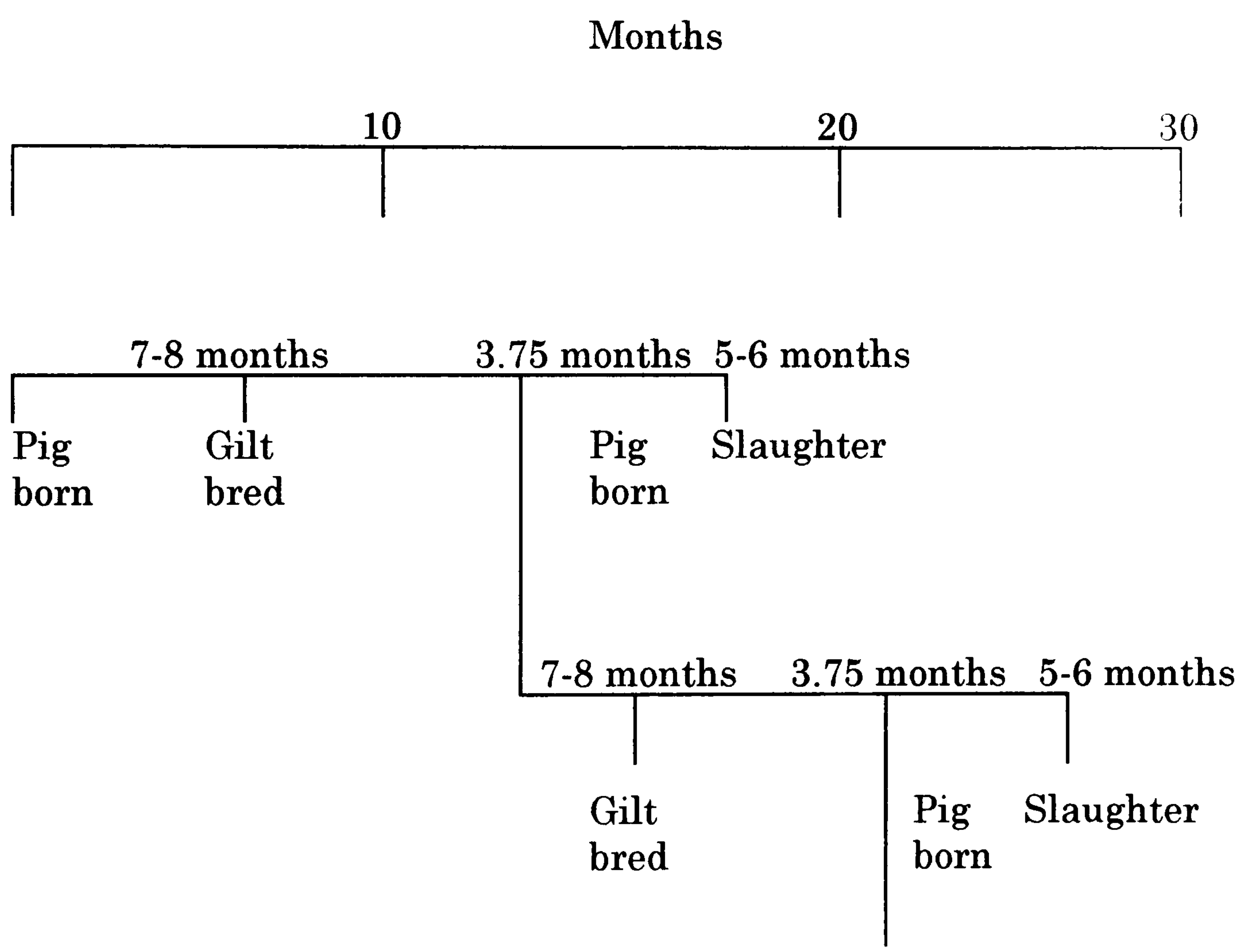


Figure 3.3 Hog Biological Lag (Pork Production Cycle)

Source: U. S. Department of Agriculture, Economics, Statistics, and Cooperative Service, February 1979.

By the 1950's swine producers began using a multiple farrowing system (Fowler, 1957); breeding is scheduled so that the litters arrive in several farrowing periods throughout the year (Ensminger and Parker, 1984). Multiple farrowing removes some of the market risks because the producer is never caught with a large number of hogs when prices are low and will always have a some to sell when prices are high (Fowler, 1957).

This study uses pig crops in December through February, March through May, June through August, and September through November as quarter 1 (Qtr I), quarter 2 (Qtr II), quarter 3 (Qtr III), and quarter 4 (Qtr IV), respectively. This may be accomplished by following a schedule such as shown in Table 3.1.

Currently, many Midwest crop and mid-size hog farms use two-sow herds and farrow four times a year: early March (before planting), mid-June (after corn planting), late August (before harvesting corn), and mid-December (after harvest and fall plowing) (Spinelli and Duewer, 1991). Hog production is the dominant enterprise on many farms, and scheduling of farrowings to control the flow of animals to the various capital-intensive housing facilities is critical. With this new approach to production, the seasonality of farrowing moderated.

Hayenga et al. (1985) indicate that the increasing importance of large enterprises has tended to level production throughout the year. Figure 3.4

Table 3.1. Plan to Produce Four Pig Crops Per Year.

Sow Group	Breed	Farrow	Sell	Rebreed	Farrow	Sell
A	Feb 1	May 25	Nov 25	Aug 1	Nov 22	May 22
B	May 1	Aug 22	Feb 22	Nov 1	Feb 22	Aug 22

Source: S. H. Fowler. "The Marketing of Livestock and Meat," Illinois: The Interstate, 1957, p. 164.

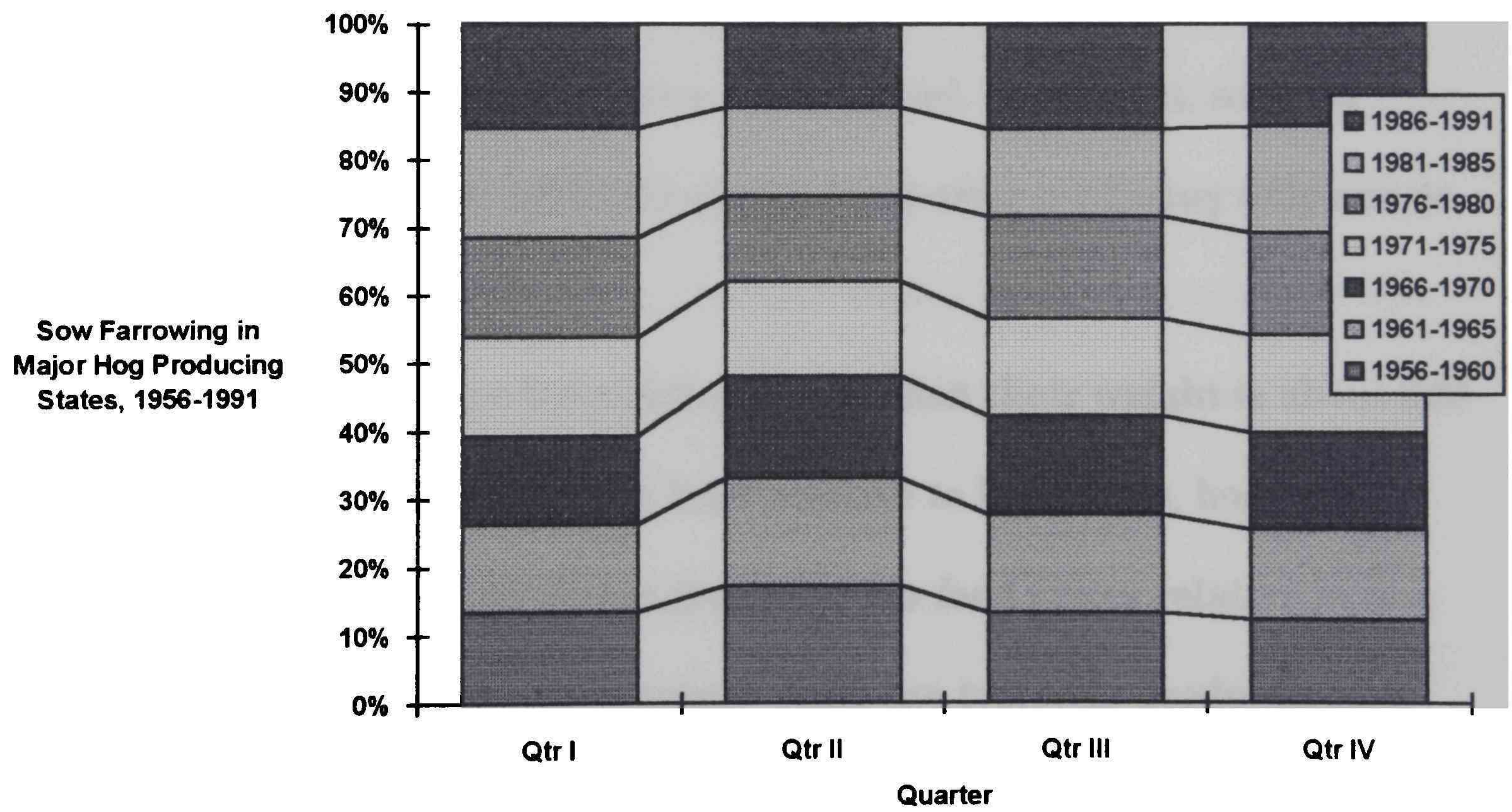


Figure 3.4 Distribution of Sow Farrowing by Quarter in Major Hog Producing States, 1956-1991.

Source: Hogs and Pigs Reports.

shows that hog production has been spread out almost equally from season to season since 1976. As a result, the seasonal variation is less variable than before.

Litters range from 5 to 15 pigs, with a recent average of slightly under 9. The pigs are weaned (taken away from their nursing mothers) six weeks after birth. Between farrowing and weaning, an average of slightly less than two pigs is lost, more during severe winters, so an average of about seven pigs survive weaning. The litter size reported by the USDA refers to pigs surviving weaning.

Although sows can produce two litters each year for several years, they become heavier the more litters they produce and, as a result, sell at a discount. Sows are, thus, typically slaughtered after producing only one or two litters.

Recently, hogs have been slaughtered when their weight is about 220 pounds. When the price of feed is high relative to hog prices, hogs are usually slaughtered at lighter weights; at lower feed prices relative to hog prices, they are fed to heavier weights. Hogs are typically produced in a single unit often called a "farrow-to-finish" production.

Feed costs represent the highest portion of the total costs of hog production. Feed costs, mainly corn and soybean meal, represent approximately 38% of total costs. On the average, about 4.4 pounds of feed are required to produce each pound of slaughter hog.

3.3 Fundamental of Market Model

In order to produce hogs and sell hogs each quarter, the producers must plan production using price expectations.

One fundamental demand market model contains the five basic equations used: the demand, the supply, desired level pig crop, stock adjustment, and market bearing equation.

3.3.1 Demand

Demand (or derived demand) depends on the real price of hog, real disposable income, real price of competing commodities, real wages at the packing industry, dummy variables, and time. The demand equation is expressed as follows:

$$Q_t^d = a + bP_t + cDPI_t + dPBR_t + ePBF_t + fWPC_t + \sum_{i=1}^{3} h_i D_i + v\,Time + u_{1,t}. \qquad (3.1)$$

where

Q_d^t = real quantity demanded of hogs at quarter t,

P_t = real hog price at quarter t,

DPI_t = real disposable personal income at quarter t,

PBR_t = real price of broiler at quarter t,

PBF_t = real price of beef at quarter t,

WPC_t = real wages at packing industry at quarter t,

D_i = seasonal dummy variable, where i = 1,2,3,

T = time trend or trend factor, and

$u_{1,t}$ = serially uncorrelated disturbances with zero mean and constant variances.

All price vectors in the demand equation are deflated by the Consumer Price Index (CPI). The standard economic theory implies the sign of the estimated regression coefficients to be:

$$\hat{b} = (-)$$

$$\hat{c} = (+)$$

$$\hat{d} = (+)$$

$$\hat{e} = (+)$$

$$\hat{f} = (-).$$

3.3.2 Supply

Production of hogs depends on the pig crop lagged two quarters (quarterly dummy variables) and time trend (or level of technology). Pig crop

(Pig_{t-2}) includes a two-period lag because a five to six month period is required to raise a pig to a market slaughter weight hog. Figure 3.3 shows that the gestation period for a pig is 3.75 months, and that the maturation period required for a pig to become a hog is 6 months.

3.3.2.1 Supply Equation

The supply equation is expressed as follows:

$$Q_t^s = \alpha_o + gPig_{t-2} + \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}. \tag{3.2}$$

where

Q_t^s = hog slaughter at time t,

Pig_{t-2} = pig crop two quarters previously,

Time = time or trend factor,

k_i = seasonal dummy variables, for i = 1,2,3,

$u_{2,t}$ = serially uncorrelated disturbances with zero mean and constant variances.

$$\hat{g} = (+)$$

Expected sign of the estimate is:

3.3.2.2 Desired Level Pig Crop

The desired level of pig crop in the confinement house at time t-2 depends on the expected price of hogs at time t using information available at time t-4, $\{E_{t-4}(P_t | I_{t-4})\}$ and real price of corn at time (t-4), real interest rate at

$$\begin{aligned} Pig^*_{t-2} &= po + p\,E_{t-4}P_t + q\,PC_{t-4} + r\,IR_{t-4} \\ &+ \sum_{i=1}^{3} e_i\,D_i + n\,Time + u_{3,t}. \end{aligned} \tag{3.3}$$

time t-4, seasonal dummy variables, and time trend.

where

Pig^*_{t-2} = desired level of pig crop at time t - 2,

$E_{t-4}(P_t | I_{t-4})$ = the expected price of hog two quarters ahead by forming expectations at time t - 4,

PC_{t-4} = real price of corn at time t - 4,

IR_{t-4} = real interest rate at time t - 4, and

$u_{3,t}$ = white noise.

Expected signs of the estimates are:

$$\hat{p} = (-), \text{and}$$

$$\hat{r} = (-).$$

The full explanation for the negative results of $\hat{p}$ will be discussed later in this chapter. Because the price of corn and the interest rate are factors of the production, both inputs should have a negative relationship with the desired pig crop.

$$Pig_t - Pig_{t-2} = \lambda\left(Pig_t^* - Pig_{t-2}\right). \tag{3.4}$$

3.3.2.3 Stock Adjustment Equation

The dynamic behavioral equation describes the attempt of producers to narrow the gap between the actual and the desired level of pig crop, where λ $(O < \lambda \leq 1)$ is known as the coefficient of adjustment, $(Pig_t - Pig_{t-2})$ is actual change of pig crop, and $(Pig_t^* - Pig_{t-2})$ is desired change of pig crop. The parameter λ is the positive proportion of the actual change of pig crop and desired change of pig crop.

3.3.3 Market Clearing Condition

To close the model, it is assumed that the market cleared in every quarter so that

$$Q_t^d = Q_t^s = Q_t,$$

where Q_t represents both quantity bought and sold in quarter t.

3.4 Producers' Expectations

A fundamental model can be modified into two models (Model I and Model II) depending on the method of forming hog price expectations. In order to produce and sell hogs each quarter, the producers must plan production using the different methods of expectations in the desired pig crop equation. This study can be characterized into two models.

Basically, there are many kinds of expectations models which have been used previously for the hog producers by the researchers, in particular the hog corn price ratio at time t-4 or price of hog at time t-4. Recently, there has been no application of the rational expectation model to the hog market. Therefore, this study includes rational expectations in the market model as well as the price risk. This model differs from the eleven models discussed in the literature review in Chapter II because this study included Rational Expectations and also stock adjustment equation into the model. So, the fundamental model will be modified to create two models depending on the method of forming expectations, such as rational expectations price or rational expectations with price risk.

In Model I the producers form expectations by using all the information available. This model is called a Rational Expectations Model of Hogs. Muth (1961) and Pashigian (1970) suggest that producers' price expectation $E_{t-4}(P|I_{t-4})$ is positively correlated with actual prices (P_t) (see also Newberry and Stiglitz, 1981). For example, hog producers rely on $E_{t-4}(P_t | I_{t-4})$ to provide their price expectations. I_{t-4} is the information available at time t-4 which includes pig crop, price of hog, price of price of corn, interest rate, disposable income, price of broilers, price of beef, technology, and seasonal variations. When the producers' price expectations $E_{t-4}(P_t | I_{t-4})$ of hogs increase, then the pig crop (Pig_{t-2}) at time t-2 decreases. As a result, hog slaughter (Q_t) decreases and the actual price increases.

Newberry and Stiglitz (1981) explain how the smart farmer (or speculator) can make a profit by using countercyclical strategy:

> Suppose that farmers have some theory about the way their economic environment works, and that this theory is consistent with observations. They observe that price is low when their own supply is large, and they postulate a downward sloping aggregate demand schedule, although they also realize that they would sell as much as they like at the prevailing market price. (p. 135)

In Model II, model estimation and analysis may be facilitated by giving the assumptions as follows:

(1) the hog producers are aware of previous price risk of live hog and corn,

(2) it takes more than one year to make the decisions in order to produce hogs because they expect the price of hogs from time t-5 to time t; this assumes the long run study. In the long term

expectations, the size of the plant, as well as the amount of output from the plant, is variable. In this model, producers form price expectations for more than one year (beginning from time t-5).

(3) tendency toward negative profits have existed over a long period of time (see Figure 2.4).

Model II is different from Model I because the risk from varying hog and corn prices are included in Model II. Some risk must be borne by all businessmen, but hog producers are especially subject to considerable price risk. These expectational characteristics of Model II are known as the rational expectations with price risks.

The hog producers are aware of previous price risk of hogs and corn because a tendency toward negative profits has existed over a long period of time. If the hog producers need to increase production, then they must ensure that the price expectations trend (EXPCH) is positive because they experienced price risk extensively in the past. Accordingly, there is a positive relationship between the positive trend of hog price expectations, $EXPCH = E_{t-4}(P_t|I_{t-4}) - E_{t-5}(P_{t-1}|I_{t-5})$, and the desired level of pig crops at time t-2 (Pig^*_{t-2}).

From Figure 3.5, in quarter t-5 for the beginning, they might try to anticipate the hog price at time t-1. In mathematical relations, $E_{t-5}(P_{t-1}|I_{t-5}) = P_{t-1}$, where I_{t-5} is the information set available at time t-5

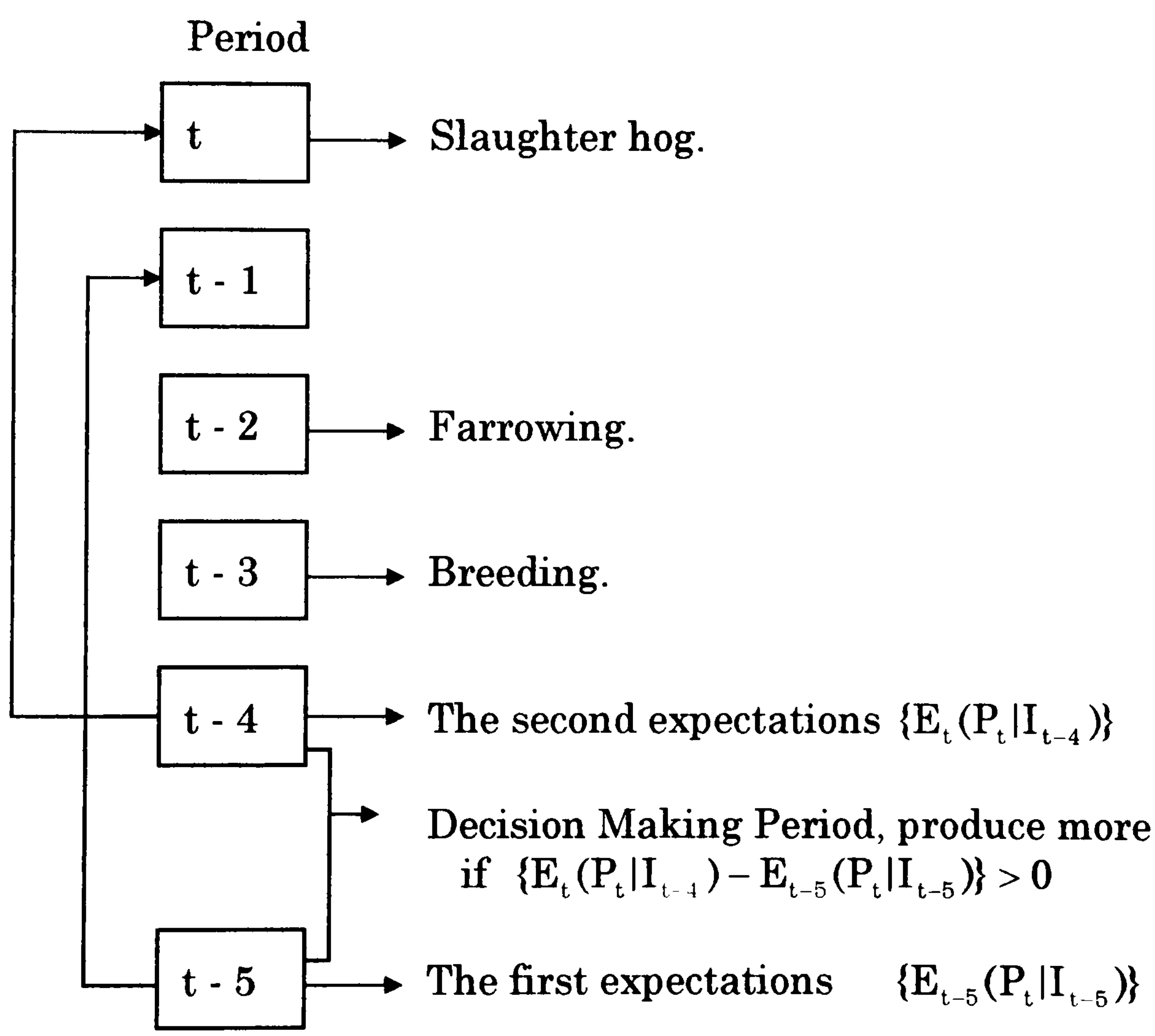


Figure 3.5. The Decision-Making Period for Model II.

which includes pig crop, price of hog, price of corn, price risks, interest rates, disposable income, price of broilers, price of beef, wages at the packer level, technology, and seasonal variations.

In quarter t-4, they try to anticipate hog price in quarter t, that is $E_{t-4}(P_t | I_{t-4})$. Or, they might try to use the hog price in quarter t-4 as the expected price at time t. Then, the producers form expectations by using the change of expectations (price expectations trend) between $E_{t-4}(P_t | I_{t-4})$ and $E_{t-5}(P_{t-1} | I_{t-5})$, that is, $\text{EXPCH} = E_{t-4}(P_t | I_{t-4}) - E_{t-5}(P_{t-1} | I_{t-5})$. Therefore, the decision-making period for the hog producer is time t-4 and t-5.

After the hog producers form the price expectations trend, through the desired pig crop and the quantity adjustment, they can anticipate the number of hogs that they plan to produce. They would look for the procurements which are all kinds of the factors of production for producing hogs in quarter t.

Quarter t-3 is the period of breeding. By the end of quarter t-3, the pigs are born. Quarters t-2 and t-1 are the periods of feeding pigs. Once born, the pig crop becomes marketable at the approximate age of six months.

To summarize, a simple model of an auction market for an agricultural commodity will be used as the following. Demand for hogs at time t depends on current price of hogs, substitute meat prices, wages at the packer level, disposable income, seasonal variations, and time trend. Supply of hogs at time t depends on pig crop at time t-2, seasonal variations, and time trend. Pig crop derived from the pig crop adjustment equation included desired pig crop. The desired pig crop depends on price expectations, price of corn, labor wages, interest rate, seasonal variation, and time trend. Two kinds of expectations are $E_{t-4}(P_t|I_{t-4})$ and EPCH = $E_{t-4}(P_t|I_{t-4}) - E_{t-5}(P_t|I_{t-5})$. These are incorporated in the desired pig crop equation to reflect the fact that hog production depends on the future price expectations.

3.5 The Relationship Between Rational Expectations Hypothesis and Market Efficiency Hypothesis

The development of market efficiency in the futures market is completely dependent on the development of rational expectation hypothesis, (from Muth's [1961] work). The futures market provides two important social benefits, risk management through hedging and price discovery. Theoretically, expectations in futures markets should equal to optimal forecasts using all available information. Therefore, for an efficient market, all unexploited profit opportunities will be eliminated. In fact, the efficient market is just an implication of rational expectations to the pricing of futures market, because when expectations are formed rationally all relevant information about the economic situation is used to predict future prices.

Thus, both rational expected price forecast and futures prices are unbiased forecasts of the subsequent spot price, therefore $P_t = P^{f,t}_{t-4} = P^{e,t}_{t-4}$.

Even though a rational expectations forecast uses all available information, the expectations may not be perfectly accurate. Mishin (1989) states that there are two reasons why an expectation may fail to be rational. First, people might be aware of all available information, but they do not take the time to fully utilize it to obtain the best guess possible. Second, people might be unaware of some available relevant information, so their best guess of the future will not be correct on average. Therefore, $P_t \neq P^{e,t}_{t-4}$.

The futures price is normally higher than the spot price for storable commodities. Commodities like fresh eggs, fresh potatoes, hogs are unstorable. For hogs the theory of carrying cost is irrelevant, and, as a result, subsequent spot prices often exceed futures prices. Therefore, expected price at time t-4 is not equal to futures price at time t-4, $P_t \neq P^{f,t}_{t-4}$. Empirically, the price forecasts derived from the hog futures price may be more or less accurate than the rational expectations models or vice versa.

CHAPTER IV

METHOD AND PROCEDURES

4.1 Data

In structural models, the specification problem involves judgment about the independent variables to be used and the form of causal relationship. A quarterly model of the hog sector is specified in this chapter.

The most important source of information is the Hogs and Pigs Report published quarterly around the 22nd of March, June, September, and December (Crop Reporting Board of the Statistical Reporting Service of the USDA). This report, based on a survey taken about three weeks earlier, covers all states during December and June and the 10 major hog-producing states during March and September. The report provides data by state on the number of sows farrowing, the number of pigs saved per sow, and the total number saved. It also gives producers' intentions for sows farrowing during the next two quarters.

The Livestock Slaughter Report, published monthly (on or about the 20th) also by the USDA, provides data on hog slaughter. Livestock and Meat Statistics, an annual publication of the USDA, provides more detailed data on a historical basis. The Weekly Livestock, Meat and Wool Market News, also published by the USDA, provides extensive data on hogs and pork. The

Livestock and Meat Outlook and Situation is published by USDA six times a year and provides historical information on the livestock and meat markets. Feed Situation, a quarterly report published by the USDA, provides data on the feed industries.

The Chicago Mercantile Exchange Yearbook contains daily prices, volume, and open interest for each futures contract, daily cash prices, and useful statistical information related to the supply of and demand for hogs, pork, and pork bellies. Producers can refer to the Wall Street Journal, which gives a sample of the daily listing for commodities which includes both futures prices and cash (spot) prices.

The variables in the model specified in equations (4.1) through (4.4) and the sources of the data are listed below:

Q^d_t = Quantity demanded of hogs, U.S. 1,000 head at time t, USDA Crop Reporting Board, Wall Street Journal.

CPI = Consumer Price Index for all urban consumers, U.S. average (not seasonally adjusted (1967 = 100), Survey of Current Business.

P_t = Hog price at time t, dollars per cwt, USDA Crop Reporting Board, Wall Street Journal.

DPI_t = Disposable personal income at time t, 1 billion per unit, Survey of Current Business.

PBR_t = Price of broilers at time t, in cents per pound, Meat and Poultry Situation and Outlook.

PBF_t = Price of beef at time t, in cents per pound, Meat and Poultry Situation and Outlook.

WPC_t = Average hourly earnings per worker, Survey of Current Business.

Q^s_t = Quantity supplied for hogs at time t, USDA Crop Reporting Board, Wall Street Journal.

Pig_{t-2} = Pig crop two quarters previously, thousand head, USDA Crop Reporting Board, Wall Street Journal.

$E_{t-4}(P_t | I_{t-4})$ = The expected price of hog four quarters ahead by forming expectation at time (t-4) with information at time (t-4).

PC_t = Price of corn lagged one quarter, in cents per bushel, USDA Crop Reporting Board, Wall Street Journal.

PPI = Production price indexes, 1967 = 100, Agricultural Outlook.

IR_t = Interest rate annually, Agricultural Outlook.

WF = Labor and management per hour, Agricultural Outlook.

HCR_t = The hog-corn ratio, Commodity Year Book.

T = Trend factor, the time variable as a trend factor may be used as a proxy variable of the effect of changes in technology.

4.2 Justification of Variables

4.2.1 Cold Storage and Foreign Trade

There are cold storage stocks of pork, which are equivalent to only 2% to 3% of annual pork production. This study excludes cold storage from the model because of the small size of pork stocks. Higginson et al. (1988)

studied the relationship between U.S. hog imports and the price of swine in the U.S. The authors found that Canadian swine imports into U.S. markets did not have a significant effect on U.S. prices. For these reasons, this study excludes foreign sectors from the model.

4.2.2 Wages at Packers' Level

It is important to distinguish between types of demand. Direct demand is based on the utility or satisfaction obtained directly from the purchase of a specific commodity, such as pork, whereas derived demand is based on direct demand. In the case of hogs, derived demand depends on the determinants of direct demand such as the price of substitute meats, income and population.

Goodwin (1977) outlined a general analysis of the relationship between retail demand and demand for hogs as follows:

> The farm demand curve for a given product is derived from the demand at retail by way of the demand curves at all the intermediate processing and marketing levels. This derivation may be accomplished by means of simply subtracting the marketing margin for any given quantity of product from retail price that consumers are willing to pay for the quantity. (p. 330)

Demand for hogs, in this case, according to Lundy and Foote (1952), is a kind of derived demand for commodities which are used as raw materials in processing operations. They include most farm products, such as livestock and cotton. The derived demand includes charges for processing along with those for transportation, assembly, distribution, and other marketing services as part of the overall marketing margin. Waite and Trelogen (1948) consider that demand in the producer's market is derived from demand in the consumer's market. That is, the price which sellers in the retail market are willing to pay to the packer is determined by their estimates of what prices the goods will bring less the margin charged by them for their services. The labor wage is the important cost in the packing industry (or slaughter house). Farris and Mathia (1981) studied the operations of pork slaughter plants and markets for Texas hogs. They found that labor cost was the major cost, accounting for 79 percent of the total cost.

Therefore, this study considers the labor cost in the packing industry to be a proxy for the marketing margin. Thus, the wages at packer level (WPC_t) should be included in the derived demand equation for hogs slaughtered.

4.2.3 Price Deflation

Price indexes are employed to "adjust" time series in dollar units so that the series can be studied without the effects of price changes. The price deflator should be used in demand equation. However, using the same price deflator index in conjunction with the supply and demand equation in the market model is inappropriate. This is because the producers' perception of the price deflator in the supply equation differs from the packers' perception of the price deflator in the demand equation.

In this study, the price vectors in demand equation are deflated by the Consumer Price Index, and the price vectors in supply equation are deflated by the Producer Price Index.

4.2.4 Seasonal Variation

Seasonal variation involves patterns of change within a year that tend to be repeated from year to year. For example, a physician can expect a substantial increase in the number of flu cases every winter and of poison ivy every summer. Some of these are regular patterns that are useful in forecasting the futures.

Many economic time series show market seasonal fluctuations. Judge (1990) explained how to take account of the problem of seasonal fluctuation. He suggested using dummy variables during estimation instead of using deseasonalized data methods. The latter method has four major problems. First, it will induce autocorrelation. Second, if different techniques of seasonal adjustment are used in the different series, then this may distort the relationships between the series. Third, one does not know the degrees of freedom used up in the adjustment technique and so cannot adjust for it when conducting tests. Finally, the cumulative averaging is a smoothing device and may tend to obscure some of the finer movements in the series which are being considered. Judge proposes to use alternative techniques of using dummy variables in attempting to overcome these problems mentioned above.

4.3 The System Estimation

For the system estimation, Bigman (1985) proposed to use the recursive method instead of the simultaneous method. He explained that in a short-run dynamic analysis, production and resource allocation decisions in any given year are made at the beginning of the year on the basis of expected prices, before the weather event and the actual prices for the year become known. Therefore, the solution method should be recursive and sequential rather than simultaneous.

Maddala and Shonkwiler (1985) consider the rational expectations model as a recursive structure. They stated that

> this system has a familiar recursive structure when the expected price variable is specified in terms of one or more lagged prices. When the restricted reduced form of the structural system is solved for in terms of the expected price and this expression is used to replace p_t^*. (p. 5)

Also, Fisher (1982) considers the rational expectation model can be solved by using the recursive method. He states that the system is recursive and the market clears in each period.

4.4 Identification of Rational Expectations Model

According to Wallis (1980), the identification condition is satisfied if the number of variables which appear as expectational variables are not more than the number of expectational exogenous variables. Desai (1981) reinforces Wallis' idea that this makes logical sense, because the variables are employed to generate the optimal predictors of the endogenous variables whose expected values appear in the structural form equations. In Model I, $E_{t-4}(P_t|I_{t-4})$ is an expectational variable and DPI_t^*, PBR_t^*, PBF_t^*, and WPC_t^* are exogenous variables. Therefore, the number of expectational variables is one, which is less than the number of expectational exogenous variables, (4).

4.5 Producers' Expected Price: Endogenous and Exogenous Variable?

Should expected price be an exogenous variable? Christ (1991) states that "to analyze the behavior of an expectation model, it is useful first to consider the model as if expectations were exogenous" (p. 283).

4.6 Steps of Estimation for Model I

Producers base future production plans on the rational expectations prices. Therefore, their expected price would be

$$E_{t-4}(P_t|I_{t-4}) = P_t \qquad (4.1)$$

The assumptions of the REH are as follows:

(1) The hog producers believe this economic model and they behave as if they know its parameters and exogenous information.

(2) The hog producers do not know the random components.

Structural Equations

Demand Equation

$$\begin{aligned} Q_t^d &= a + bP_t + cDPI_t + dPBR_t + ePBF_t + fWPC_t \\ &+ \sum_{i=1}^{3} h_i D_i + vTime + u_{1,t}. \end{aligned} \tag{4.2}$$

Supply Equation

$$Q_t^s = \alpha_o + gPig_{t-2} + \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}. \tag{4.3}$$

Desired Pig Crop Equation

$$\begin{aligned} Pig_t^* &= \rho_0 + \rho E_{t-2} P_{t+2} + qPC_{t-2} + rIR_{t-2} \\ &+ \sum_{i=1}^{3} l_i D_i + jTime + u_{3,t}. \end{aligned} \tag{4.4}$$

Pig Crop Adjustment Equation

$$Pig_t - Pig_{t-2} = \lambda\left(Pig_t^* - Pig_{t-2}\right). \tag{4.5}$$

Market Clearing Condition

$$Q_t^d = Q_t^s. \tag{4.6}$$

Steps for deriving the forecast price $(P_{t-4}^{e,t})$ of Model I are as follows:

<u>Step 1</u>: Substitute the pig crop desired level (Pig_t^*) from equation (4.4), into the stock adjustment equation (4.5).

$$Pig_t - Pig_{t-2} = \lambda(\rho_0 + \rho E_{t-2}P_{t-2} + qPC_{t-2} + rIR_{t-2} + \sum_{i=1}^{3} l_i D_i + jTime + u_{3,t} - Pig_{t-2}). \tag{4.7}$$

Lagging variables in equation (4.6) by two quarters,

$$Pig_{t-2} - Pig_{t-4} = \lambda(\rho_0 + \rho E_{t-4}P_t + qPC_{t-4} + rIR_{t-4} + \sum_{i=1}^{3} l_i D_i + jTime-2 + u_{3,t-2} - Pig_{t-4}). \tag{4.8}$$

$$Pig_{t-2} - Pig_{t-4} = \lambda\rho_0 + \lambda\rho E_{t-4}P_t + \lambda qPC_{t-4} + \lambda rIR_{t-4} + \lambda\sum_{i=1}^{3} l_i D_i + j\lambda Time-2 + \lambda u_{3,t-2} - \lambda Pig_{t-4}. \tag{4.9}$$

$$Pig_{t-2} = (1-\lambda)Pig_{t-4} + \lambda\rho_0 + \lambda\rho E_{t-4}P_t + \lambda qPC_{t-4} + \lambda rIR_{t-4} + \lambda\sum_{i=1}^{3} l_i D_i + j\lambda Time-2 + \lambda u_{3,t-2}. \tag{4.10}$$

<u>Step 2</u>: Then, substitute Pig_{t-2} from equation (4.10) into supply equation (4.3).

$$Q_t^S = \alpha_0 + g[(1-\lambda)Pig_{t-4} + \lambda P_o + \lambda P_o E_{t-4}P_t + \lambda qPC_{t-4} + \lambda rIR_{t-4} + \lambda \sum_{i=1}^{3} l_i D_i + \lambda jTime-2 + \lambda u_{3,t-2}] + \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}. \tag{4.11}$$

$$= \alpha_o + g(1-\lambda.)Pig_{t-4} + g\lambda\rho_0 + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} + g\lambda rIR_{t-4} + g\lambda\sum_{i=1}^{3} l_i D_i + g\lambda jTime-2 + g\lambda u_{3,t-2} + \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}. \tag{4.12}$$

$$= \alpha_o + g(1-\lambda.)Pig_{t-4} + g\lambda\rho_0 + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} + g\lambda\, rIR_{t-4} + g\lambda\sum_{i=1}^{3} l_i D_i + g\lambda\, jTime-2 + \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t} + (g\lambda u_{3,t-2}). \quad (4.13)$$

<u>Step 3</u>: Then, equilibriate $Q_t^d = Q_t^s$ to get the market clearing condition (4.6).

$$\begin{aligned} &a + bP_t + cDPI_t + dPBR_t + ePBF_t + fWPC_t + \sum_{i=1}^{3} h_i D_i + vTime + u_{1,t} \\ &= \alpha_o + g(1-\lambda)Pig_{t-4} + g\lambda\rho_o + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} + g\lambda\, rIR_{t-4} \\ &+ u_2 + g\lambda u_{3,t-2} + \sum_{i=1}^{3}(k_i + g\lambda l_i)D_i + nTime + g\lambda\, jTime-2. \end{aligned} \quad (4.14)$$

$$\begin{aligned} bP_t - q\lambda\rho E_{t-4}P_t = {} & \alpha_o + g(1-\lambda)Pig_{t-4} + g\lambda\rho_0 + g\lambda q\,PC_{t-4} + g\lambda\, rIR_{t-4} \\ & + \sum_{i=1}^{3}(k_i + g\lambda l_i)D_i + nTime + g\lambda\, jTime-2 \\ & - a - cDPT_t - dPBR_t - ePBF_t - fWPC_t \\ & - \sum_{i=1}^{3}(h_i)D_i - vTime + u_{1,t} + u_{2,t} + g\lambda u_{3,t-2}. \end{aligned} \quad (4.15)$$

$$\begin{aligned} bP_t - g\lambda\rho E_{t-4}(P_t) = {} & (\alpha_o - a + g\lambda\rho_0) + g(1-\lambda)Pig_{t-4} + g\lambda qPC_{t-4} \\ & + g\lambda\, rIR_{t-4} - cDPI_t - dPBR_t - ePBF_t - fWPC_t \\ & + \sum_{i=1}^{3}(k_i + g\lambda l_i - h_i)D_i + (n-v)Time \\ & + g\lambda\, jTime-2 + u_{1,t} + u_{2,t} + g\lambda u_{3,t-2}. \end{aligned} \quad (4.16)$$

<u>Step 4</u>: Take expectation $E_{t-4}(\ \ |I_{t-4})$ through equation (4.16).

$$\begin{aligned} (b - g\lambda\rho)E_{t-4}(P_t) = {} & (\alpha_o - a + g\lambda\rho_0) + g(1-\lambda)Pig_{t-4} + g\lambda qPC_{t-4} \\ & + g\lambda\, rIR_{t-4} - cE_{t-4}DPI_t - d\,E_{t-r}\,PBR_t \\ & - eE_{t-4}PBF_t - fE_{t-4}WPC_t \\ & + \sum_{i=1}^{3}(k_i + g\lambda l_i - h_i)D_i + (n+v)Time + g\lambda jTime-2. \end{aligned} \quad (4.17)$$

Step 5: Let

$$E_{t-4}DPI_t = DPI_t^*,$$
$$E_{t-4}PBR_t = PBR_t^*,$$
$$E_{t-4}PBF_t = PBF_t^*, \text{ and}$$
$$E_{t-4}WPC_t = WPC_t^*.$$

Then,

$$\begin{aligned} E_{t-4}(P_t | I_{t-4}) = \frac{1}{(b - g\lambda\rho)} [(\alpha_o - a + g\lambda\rho_0) + g(1-\lambda)Pig_{t-4} + g\lambda qPC_{t-4} \\ + g\lambda rIR_{t-4} - cDPI_t^* - dPBR_t^* - ePBF_t^* - fWPC_t^* \\ + \{\sum_{i=1}^{3}(k_i + g\lambda l_i - h_i)D_i + (n-u)Time + g\lambda jTime-2.. \end{aligned} \tag{4.18}$$

Let

$$(b - g\sigma\rho) = \Omega \rangle 0.$$
$$\beta_i = k_i + g\lambda l_i - h_i$$
$$\gamma_5 = n + v.$$
$$\gamma_6 = g\lambda j_i$$

Then,

$$\begin{aligned} E_{t-4}(P_t | I_{t-4}) = \frac{1}{\Omega}[\gamma_1 + \gamma_2 Pig_{t-4} + \gamma_3 qPC_{t-4} + \gamma_4 rIR_{t-4} \\ - cDPI_t^* - dPBR_t^* - ePBF_t^* - fWPC_t^* \\ + \{\sum_{i=1}^{3}(\beta_i)D_i\} + \gamma_5 Time + \gamma_6 Time-2]. \end{aligned} \tag{4.19}$$

Thus,

$$\begin{aligned} E_{t-4}(P_t | I_{t-4}) = \frac{\gamma_1}{\Omega} + \frac{\gamma_2}{\Omega}Pig_{t-4} + \frac{\gamma_3}{\Omega}PC_{t-4} + \frac{\gamma_4}{\Omega}IR_{t-4} \\ - \frac{c}{\Omega}DPI_t^* - \frac{d}{\Omega}PBR_t^* - \frac{d}{\Omega}PBF_t^* - \frac{f}{\Omega}WPC_t^* \\ + \frac{1}{\Omega}\{\sum_{i=1}^{3}(\beta_i)D_i\} + \frac{\gamma_5}{\Omega}Time + \frac{\gamma_6}{\Omega}Time-2. \end{aligned} \tag{4.20}$$

This model will express $E_{t-4}(P_t|I_{t-4})$ as a function of PC_{t-4}, IR_{t-4}, DPI^*_t, PBR^*_t, PBF^*_t, WPC^*_t, dummy variables, Time and time t-2 It is assumed that the producers form their expectations based on all parameters and exogenous information. Therefore, the expected price is a function of the expected values of the exogenous variable (DPI^*_t, PBR^*_t, PBF^*_t, WPC^*_t,) and other exogenous variables (Pig_{t-4}, PC_{t-4}, IR_{t-4}, D_i, and Time) that drive the model.

The reduced form of producers price expectation is:

$$\begin{aligned} E_{t-4}(P_t|I_{t-4}) = F(&Pig_{t-4}, PC_{t-4}, IR_{t-4}, DPI^*_t, PBR^*_t, \\ &PBF^*_t, WPC^*_t, D_1, D_2, D_3, \text{Time}, \text{Time}-2). \end{aligned} \tag{4.21}$$

In this step substitute $E_{t-4}(P_t|I_{t-4})$, DPI^*_t, PBR^*_t, PBF^*_t, WPC^*_t by the actual values P_t, DPI_t, PBR_t, PBF_t, WPC_t respectively. Then run a regression of P_t on $Pig_{t-4}, PC_{t-4}, IR_{t-4}, DPI_t, PBR_t, PBF_t, WPC_t, D_1, D_2, D_3$, Time and Time - 2. In this step producers' price expectation is endogenous variable.

Step 6: Insert $E_{t-4}(P_t|I_{t-4})$ (to be an exogenous variable) into the pig crop equation (with the desired pig crop) to get the estimated pig crop at quarter t-2 (Pig_{t-2}).

$$Pig_{t-2} = F[E_{t-4}(P_t|I_{t-4}), Pig_{t-4}, PC_{t-4}, IR_{t-4}, D_1, D_2, D_3, \text{Time}-2]. \tag{4.22}$$

Pig-crop equation:

Then, substitute the estimated pig crop into equation (4.22) to get the estimated quantity supplied.

$$Q_t = F(Pig_{t-2}, D_1, D_2, D_3, Time). \qquad (4.23)$$

Finally, substitute the quantity supplied (Q_t) into the demand equation to get the forecast price of hog, $P^{e,t}_{t-4}$.

$$P^{e,t}_{t-4} = F(Q_t, DPI_t, PBR_t, PBF_t, WPC, D1, D2, D3, Time). \qquad (4.24)$$

Demand equation:

4.7 Steps of Estimation for Model II

Steps of deriving the forecast price $P^{e,t}_{t-4}$ for Model II are as follows.

$$Expch = E_{t-4}(P_t | I_{t-4}) - E_{t-5}(P_{t-1} | I_{t-5})$$

Producers base their production plans on the change of expectations. assuming that producers have the same price risk.

VP_{t-4}, the hog price risk perceived at time t-4, is the summation of the square of hog price that deviates from the means of hog price from time t-4 to time t-10.

$$VP_{t-4} = \sum_{i-4}^{10} (P_{t-1} - AP)^2,$$

The price risk of hogs in this case is:

where

i = 4, 5, ..., 10 (7 quarters) and

AP is the mean of the hog price from time t-4 to time t-10.

The price risk of corn is

where

i = 4, 5, ..., 8 (5 quarters) and

VPC_{t-4}, the corn price risk perceived at time t-4, is the summation of the square of corn price that deviates from the means of corn price from time t-4 to time t-8.

$$VPC_{t-4} = \sum_{i=4}^{8}(PC_{t-1} - APC)^2,$$

$$AP = \frac{\sum_{i=4}^{10} P_{t-i}}{7}.$$

APC is the mean of the corn price from time t-4 to time t-8.

$$APC = \frac{\sum_{i=4}^{8} PC_{t-i}}{5}.$$

where i=4,5,...,8 (5 quarters).

The numbers, i = 4, 5, ..., 10, were chosen for the hog price risk because the producers have perceived the hog price instability. Relatively, the hog price has more instability than the corn price. In other words, the producer weights the kind of loss differently. If losses attributable to the hog prices are incurred period after period, the hog producer will become more aware of these types of losses. Therefore, the producer will give more weight to the hog prices than to the corn prices. That is why the short-range period has been chosen for the corn price, i.e., i = 4, 5, ..., 8. The numbers used were chosen arbitrarily to ensure that the producers' perception will remain intact over time.

For Model II the estimation technique is the same as Model I, except this model uses expected change of price and price risks.

Structural Equations

Demand Equation:

$$Q_t^d = a + bP_t + cDPI_t + dPBR_t + ePBF_t + fWPC_t + \sum_{i=1}^{3} h_i D_i + vTime + u_{1,t}. \tag{4.25}$$

Supply Equation:

$$Q_t^s = \alpha_o + gPig_{t-2} + \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}. \tag{4.26}$$

Desired Pig Crop Equation:

$$Pig_t^* = \rho_o + \rho E_{t-2} P_{t+2} + qPC_{t-2} + rIR_{t-2} + xWF_{t-4} + wVP_{t-2} + kVPC_{t-2} + \sum_{i=1}^{3} l_i D_i + jTime + u_{3,t}. \tag{4.27}$$

Pig Crop Adjustment Equation:

$$\mathrm{Pig}_t - \mathrm{Pig}_{t-2} = \lambda\left(\mathrm{Pig}_t^* - \mathrm{Pig}_{t-2}\right). \tag{4.28}$$

Market Clearing Condition:

$$Q_t^d = Q_t^s. \tag{4.29}$$

Steps for deriving the producer rational expectations price of Model II are as follows:

Step 1: Substitute the pig crop desired level (4.27) into the stock adjustment equation (4.28), then lag two quarters to get Pig_{t-2}.

$$\mathrm{Pig}_{t-2} = \mathrm{Pig}_{t-4} + \lambda(\mathrm{Pig}_{t-2}^* - \mathrm{Pig}_{t-4}).$$

The desired pig crop is a function of price expectations at time t observed at time t-4 $E_{t-4}(P_t|I_t)$, price of corn at time t-4 (PC_{t-4}), interest rate at time t-4 (IR_{t-4}), wages at farm level (WF_{t-4}), seasonal dummy variable and Time trend.

$$\begin{aligned}\mathrm{Pig}_t - \mathrm{Pig}_{t-2} = \lambda(&\rho_o + \rho E_{t-2}P_{t+2} + qPC_{t-2} + rIR_{t-2} \\ &+ xWF_{t-4} + w\,VP_{t-2} + k\,VPC_{t-2} \\ &+ \sum_{i=1}^{3} l_i D_i + j\mathrm{Time}-2 + u_{3,t} - \mathrm{Pig}_{t-2}).\end{aligned} \tag{4.30}$$

Lagging variables in equation (4.30) by two quarters:

$$\begin{aligned}\mathrm{Pig}_{t-2} - \mathrm{Pig}_{t-4} = \lambda(&\rho_0 + \rho E_{t-4}P_t + qPC_{t-4} + rIR_{t-4} \\ &+ xWF_{t-4} + \omega\,VP_{t-4} + \kappa\,VPC_{t-4} \\ &+ \sum_{i=1}^{3} l_i D_i + j\mathrm{Time}-2 + u_{3,t-2} - \mathrm{Pig}_{t-4}).\end{aligned} \tag{4.31}$$

$$\begin{aligned}Pig_{t-4} - Pig_{t-4} &= (\lambda\rho_o + \lambda\rho E_{t-4}P_t + \lambda qPC_{t-4} + \lambda rIR_{t-4} \\ &+ \lambda nW F_{t-4} + \lambda wVP_{t-4} + \lambda kVPC_{t-4} \\ &+ \sum_{i}^{3} l_i D_i + jTime - 2 + \lambda u_{3,t-2}).\end{aligned} \tag{4.32}$$

$$\begin{aligned}Pig_{t-2} &= (1-\lambda)Pig_{t-4} + \lambda\rho_o + \lambda\rho E_{t-4}P_t + \lambda qPC_{t-4} + \lambda rIR_{t-4} \\ &+ \lambda n WF_{t-4} + \lambda wVP_{t-4} + \lambda kVPC_{t-4} \\ &+ \lambda\sum_{i=1}^{3} l_i D_i + jTime - 2 + \lambda u_{3,t-2}.\end{aligned} \tag{4.33}$$

<u>Step 2</u>: Substitute Pig_{t-2} (with desired pig crop) into the supply equation (4.26).

$$\begin{aligned}Q_t^s &= \alpha_o + g[(1-\lambda)Pig_{t-4} + \lambda\rho_o + \lambda\rho E_{t-4}P_t + \lambda qPC_{t-4} + \lambda\rho IR_{t-4} \\ &+ \lambda x WF_{t-4} + \lambda\omega VP_{t-4} + \lambda k VPC_{t-4} \\ &+ \lambda\sum_{i=1}^{3} \lambda_i D_i + \lambda jTime - 2 + \lambda u_{3,t-2}] \\ &+ \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}.\end{aligned} \tag{4.34}$$

$$\begin{aligned}&= \alpha_o + g(1-\lambda)Pig_{t-4} + g\lambda\rho_0 + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} + g\lambda rIR_{t-4} \\ &+ g\lambda x WF_{t-4} + g\lambda\omega VP_{t-4} + g\lambda k VPC_{t-4} \\ &+ g\lambda\sum_{i=1}^{3} l_i D_i + g\lambda jTime - 2 + g\lambda u_{3,t-2} \\ &+ \sum_{i=1}^{3} k_i D_i + nTime + u_{2,t}.\end{aligned} \tag{4.35}$$

$$\begin{aligned}Q_t^s &= \alpha_o + g(1-\lambda)Pig_{t-4} + g\lambda\rho_o + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} + g\lambda rIR_{t-4} \\ &+ g\lambda x WF_{t-4} + g\lambda\omega VP_{t-4} + g\lambda kVC_{t-4} \\ &+ g\lambda\sum_{i=1}^{3} l_i D_i + g\lambda jTime - 2 \\ &+ \sum_{i=1}^{3} k_i D_i + nTime + (u_{2,t} + g\lambda u_{3,t-2}).\end{aligned} \tag{4.36}$$

$$\begin{aligned}&= \alpha_0 + g(1-\lambda)Pig_{t-4} + g\lambda\rho_0 + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} + g\lambda rIR_{t-4} \\ &+ g\lambda x WF_{t-4} + g\lambda wVP_{t-4} g\lambda kVC_{t-4} + \sum_{i=1}^{3}(k_i + g\lambda l_i)D_i + nTime + g\lambda jTime - 2.\end{aligned} \tag{4.37}$$

Step 3: Equilibrate $Q_t^d = Q_t^s$ to get the market clearing condition (4.29).

$$\begin{aligned}
&a+ bP_t + cDPI_t + dPBR_t + ePBF_t + fWPC_t \\
&+\sum_{i=1}^{3} h_i D_i + u\,Time + u_{1,t} \\
&= \alpha_0 + g(1-\lambda)Pig_{t-4} + g\lambda\rho_0 + g\lambda\rho E_{t-4}P_t + g\lambda qPC_{t-4} \\
&+ g\lambda\, rIR_{t-4} + g\lambda x\, WF_{t-4} + g\lambda\omega\, VP_{t-4} + g\lambda k\, VPC_{t-4} \\
&+\sum_{i=1}^{3}(k_i + g\lambda l_i)D_i + n\,Time + g\lambda j Time-2 + (u_{2,t} + g\lambda u_{3,t-2}).
\end{aligned} \tag{4.38}$$

$$\begin{aligned}
bP_t - q\lambda\rho E_{t-4}P = \alpha_o &+ g(1-\lambda)Pig_{t-4} + g\lambda\rho_o + g\lambda\rho_o E_{t-4}P_t + g\lambda qPC_{t-4} \\
&+ g\lambda\, rIR_{t-4} + g\lambda x\, WF_{t-4} + g\lambda\omega\, VP_{t-4} + g\lambda\kappa\, VPC_{t-4} \\
&+\sum_{i=1}^{3}(k_i + g\lambda 1_i)D_i + n\,Time + g\lambda\, jTime-2 \\
&-a - cDPT_t - dPBR_t + ePBF_t - fWPC_t \\
&-\sum_{i=1}^{3} h_i D_i - v\,Time - u_{1,t} + u_{2,t} + g\lambda + u_{3,t-2}
\end{aligned} \tag{4.39}$$

$$\begin{aligned}
bP_t - g\lambda\rho E_{t-4}P_t = (\alpha_0 - a + g\lambda\rho_0) &+ g(1-\lambda)Pig_{t-4} + g\lambda qPC_{t-4}\,\rho_o \\
&+ g\lambda\, rIR_{t-4} + g\lambda x\, WF_{t-4} + g\lambda\omega\, VP_{t-4} \\
&+ g\lambda k\, VPC_{t-4} - cDPT_t - dPBR_t + ePBF_t - fWPC_t \\
&+\sum_{i=1}^{3}(k_i + g\lambda 1_i - h_i)D_i + (n-v)Time \\
&+ g\lambda\, jTime-2 + u_{1,t} + u_{2,t} + g\lambda\, u_{3,t-2}.
\end{aligned} \tag{4.40}$$

Step 4: Take expectation at time t from information set at time (t-4), then get $E_{t-4}(P_t | I_{t-4})$.

Take expectation $E_{t-4}(\quad | I_{t-4})$ through equation (4.40).

$$\begin{aligned} bP_t - g\lambda\rho E_{t-4}P_t = {} & (\alpha_0 - a + g\lambda\rho_0) + g(1-\lambda)Pig_{t-4} + g\lambda qPC_{t-4} \\ & + g\lambda rIR_{t-4} + g\lambda w WF_{t-4} + g\lambda\omega VP_{t-4} \\ & + g\lambda k VPC_{t-4} - cE_{t-4}DPI_t - dE_{t-4}PBR_t \\ & + eE_{t-4}PBF_t - fE_{t-4}WPC_t \\ & + \sum_{i=1}^{3}(k_i + g\lambda l_i - h_i)D_i + (n-v)Time + g\lambda jTime - 2. \end{aligned} \tag{4.41}$$

<u>Step 5</u>: Solve for $E_{t-4}(P_t|I_{t-4})$ on the left side of the equation.

This model will express $E_{t-4}(P_t|I_{t-4})$ as a function of PC_{t-4}, IR_{t-4}, WF_{t-4}, VP_{t-4}, VPC_{t-4}, DPI_t^*, PBR_t^*, PBF_t^*, WPC_t^*, dummy variables, time, and time - 2. It is assumed that the producers form their expectations based on all parameters and exogenous information. Therefore, the expected price is a function of the expected values of the exogenous variable (DPI_t^*, PBR_t^*, PBF_t^*, WPC_t^*) and other exogenous variables (Pig_{t-4}, PC_{t-4}, VP_{t-4}, VPC_{t-4}, IR_{t-4}, WF_{t-4}, D_i, and Time and Time -2) that drive the model. Let

$$\begin{aligned} E_{t-4}DPI_t &= DPI_t^*, \\ E_{t-4}PBR_t &= PBR_t^*, \\ E_{t-4}PBF_t &= PBF_t^*, \text{ and} \\ E_{t-4}WPC_t &= WPC_t^*. \end{aligned}$$

Then,

$$E_{t-4}(P_t|I_{t-4}) = \frac{1}{(b - g\lambda\rho)}[(\alpha_o - a + g\lambda\rho_0) + g(1-\lambda)Pig_{t-4} + g\lambda qPC_{t-4} + g\lambda\, rIR_{t-4} + g\lambda x\, WF_{t-4} + g\lambda w\, VC_{t-4} + g\lambda k\, PC_{t-4} - cDPI_t^* - dPBR_t^* - ePBF_t^* - fWPC_t^* + \{\sum_{i=1}^{3}(k_i + g\lambda l_i - h_i)D_i\} + (n-v)Time + g\lambda jTime-2.. \tag{4.42}$$

Let

$$(b - g\lambda\rho) = \Omega \rangle 0.$$

$$\beta_i = k_i + g\lambda l_i - h_i$$

$$\gamma_7 = n + v$$

$$\gamma_8 = g\lambda j.$$

Therefore,

$$E_{t-4}(P_t|I_{t-4}) = \frac{1}{\Omega}[\gamma_1 + \gamma_2 Pig_{t-4} + \gamma_3 PC_{t-4} + \gamma_4 IR_{t-4} + \gamma_5 WF_{t-4} + \gamma_6 VP_{t-4} + \gamma_7 VPC_{t-4} - cDPI_t^* - dPBR_t^* - ePBF_t^* - fWPC_t^* + \{\sum_{i=1}^{3}(\beta_i)D_i\} + \gamma_7 Time + \gamma_8 Time-2]. \tag{4.43}$$

$$P = \frac{\gamma_1}{\Omega} + \frac{\gamma_2}{\Omega}Pig_{t-4} + \frac{\gamma_3}{\Omega}PC_{t-4} + \frac{\gamma_4}{\Omega}IR_{t-4} + \frac{\gamma_5}{\Omega}WF_{t-4} + \frac{\gamma_6}{\Omega}VP_{t-4} + \frac{\gamma_7}{\Omega}VPC_{t-4} - \frac{c}{\Omega}DPI_t^* - \frac{d}{\Omega}PBR_t^* - ePBF_t^* - \frac{f}{\Omega}WPC_t^* - \frac{1}{\Omega} + \{\sum_{i=1}^{3}(\beta_i D_i)\} + \frac{\gamma_7}{\Omega}Time + \gamma_8 Time-2. \tag{4.44}$$

Thus, the reduced form of producers' price expectation is:

$$E_{t-4}(P_t|I_{t-4}) = (Pig_{t-4}, PC_{t-4}, IR_{t-4}, WF_{t-4}, VP_{t-4}, VPC_{t-4}, DPI_t^*, PBR_t^*, PBF_t^*, WPC_t^*, D_1, D_2, D_3, Time, Time-2). \tag{4.45}$$

In this step substitute $E_{t-4}(P_t|I_{t-4})$, DPI^*_t, PBR^*_t, PBF^*_t, WPC^*_t for the actual values P_t, DPI_t, PBR_t, PBF_t, WPC_t respectively. Then run a regression of P_t on $Pig_{t-4}, PC_{t-4}, IR_{t-4}, VP_{t-4}, VPC_{t-4}, DPI_t, PBR_t, PBF_t, WPC_t, D_1, D_2, D_3$, Time and Time - 2.

Then, lagging the above equation by one quarter to get,

$$E_{t-5}(P_{t-1}|I_{t-5}) = P_{t-1} = F(Pig_{t-5}, PC_{t-5}, IR_{t-5}, WF_{t-5}, VP_{t-5}, VPC_{t-5}, \\ DPI^*_{t-1}, PBR^*_{t-1}, PBF^*_{t-1}, WPC^*_{t-1}, D_1, D_2, D_3, Time-1, Time-3) \tag{4.46}$$

In this step substitute $E_{t-5}(P_t|I_{t-5})$, DPI^*_{t-1}, PBR^*_{t-1}, PBF^*_{t-1}, WPC^*_{t-1} for the actual values P_{t-1}, DPI_{t-1}, PBR_{t-1}, PBF_{t-1}, WPC_{t-1} respectively. Then run a regression of P_{t-1} on $Pig_{t-5}, IR_{t-5}, VP_{t-5}, VPC_{t-5}, DPI_{t-1}, PBR_{t-1}, PBF_{t-1}, WPC_{t-1}, D_1, D_2, D_3$, Time - 1, and Time - 3.

Therefore,

$$EXPCH = \{E_{t-4}(P_t|I_{t-4}) - E_{t-5}(P_{t-1}|I_{t-5})\}$$

<u>Step 6</u>: Insert EXPCH into the pig crop equation (with desired pig crop) to get the estimated pig crop at quarter t-2.

Pig-crop equation

$$Pig_{t-2} = F(Pig_{t-4}, EXPCH, VP_{t-4}, PC_{t-4}, VPC_{t-4}, IR_{t-4}, WF_{t-4}, \\ D_1, D_2, D_3, Time-2) \tag{4.47}$$

Then, substitute the estimated pig crop (Pig_{t-2}) into equation (4.3) to get the estimated quantity supplied.

$$Q_t = F(Pig_{t-2}, D_1, D_2, D_3, Time). \quad (4.48)$$

Supply equation,

Finally, substitute the quantity supplied (Q_t) into the demand equation to get the forecast price of hog $P^{e,t}_{t-4}$.

Demand equation

$$P^{e,t}_{t-4} = F(Q_t, DPI_t, PBR_t, PBF_t, WPC_t, D_1, D_2, D_3, Time). \quad (4.49)$$

4.8 Ex Ante Forecast of Explanatory Variables

The ex ante forecast refers to the prediction of values of the dependent variable, hogs price P_t beyond the time period over which the model has been estimated. In this study, the explanatory variable has to be estimated as well, thus, the hog price forecast is conditional on these predictions of the explanatory variable.

One of the principal uses of these econometric models is for forecasting the price of hogs. Ex ante forecasts, which involve forecasting the future values before they are actually realized, are being developed here. Thus, after forecasting all the explanatory variables outside the sample, the price of hogs outside sample can then be predicted.

For example, to predict the hog price at 1986, Quarter II, then at 1985, Quarter II, each of the variables (Q_t, DPI_t, PBR_t, PBF_t, and WPC_t) in equation (4.24) and (4.49) must be predicted four steps ahead. The forecaster inserts the values of the forecast exogenous variables into the model, ex post, to produce a forecast four quarters ahead. The hog price forecast is entirely conditional on the assumptions about the structure of the model and the exogenous variables. Using a different set of exogenous assumptions would produce a different forecast.

Using the Newbold method (1988), an autoregressive (AR) model was used to generate forecasts of future values of the exogenous variables in the econometric model, (i.e., PBR_t, PBF_t, and WPC_t). In an AR model, it is necessary to fix a value for the order of the autoregression ρ. In making this choice, two considerations must be balanced. A sufficiently large enough order must be chosen to account for all the important autocorrelation behavior of the series. However, an excessive value of ρ will result in a model with irrelevant parameters; and consequently, an inefficient estimation of the important parameters will occur.

One possibility is to fix the value of ρ arbitrarily, perhaps on the basis of past experience with similar data sets. An alternative approach is to set some maximal order for ρ in the autoregression and fit, in turn, models of order ρ, ρ-1, ρ-2.... For each value of ρ, the null hypothesis that the final autoregressive parameter, ϕ_ρ, of the model is 0 is tested against a two-sided alternative. The procedure terminates when a value ρ is found for which this null hypothesis is not rejected. The aim, then, is to test the null hypothesis:

$$H_0: \ \phi_\rho = 0,$$

$$H_1: \ \phi_\rho \neq 0.$$

The test is based on the fact that, to a good approximation, the parameter estimate divided by its standard error estimate (SEE) follows a standard normal distribution when the null hypothesis is true. The decision rule is:

Reject H_0 if $\dfrac{\hat{\phi}_\rho}{S_\rho} < -Z_{\alpha/2}$ or $\dfrac{\hat{\phi}_\rho}{S_\rho} > Z_{\alpha/2}$, where α is the significance level

of the test, $\hat{\phi}_\rho$ and S_ρ are the parameter estimate and its standard error, and

$Z_{\alpha/2}$ is the number for which $P(Z > Z_{\alpha/2}) = \alpha / 2$, where Z is a standard normal random variable. When using a 5% significance level for the tests, $Z_{\alpha/2} = Z_{.025} = 1.96$. The maximum order of autoregression contemplated will be fixed at 3.

McClave and Benson (1988) used the first-order autoregressive model for their analysis by fitting the regression-autoregression pair of models. Benson and McClave found that this method reduced the error variance about 30% when compared with the error associated with the regression model. In other words, accounting for the autocorrelation between residuals, in this case, has reduced estimated prediction (and forecasting) error by about 30%.

In this study, it is assumed that forecast for Consumer Price Index at time t (and DPI_t) is needed. Therefore, the regression-autoregression pair of models is as follows.

$$CPI_t = \beta_0 + \beta_1 Time + U_t \tag{4.50}$$

and

$$U_t = \phi U_{t-1} + \varepsilon_t, \tag{4.51}$$

where

CPI_t = Consumer Price Index at time t,

U_t = error terms.

To forecast the quantity of hogs, this study used a model:

$$Q_t = c_0 + c_1 Pig_{t-4} + c_2 D_1 + c_3 D_2 + c_4 D_3 + u_t. \tag{4.52}$$

D_i = Dummy Variables when $i = 1,\ldots,3$

u_t = Error Terms

4.9 The Overlapping Observation Problem

The econometric issue in this study is related to the use of overlapping forecast horizons. In the case of k-step ahead forecasts made at sampling interval l, forecast horizons overlap if k is greater than l. This introduces a moving average (MA) process of order k-l into the forecast error. The four quarter ahead forecast data examined in this study contains overlapping horizons. Hence, moving average process, of order 3, is introduced into the error terms of bias regression estimated using four quarter ahead forecast data. If the moving average errors are to be estimated, sufficient data are required; however, insufficient data exist. Therefore, great care must be exercised to achieve maximum utilization of the scarce existing data. In this study, AR(1) will be used to approximate the moving average process. If AR(3) is used, some degree of freedom would be lost. The process to correct the serial correlation is called the Two Step Full Transform Method. SAS/ETS (1990) explains that,

> The method is generalized least squares using the OLS residuals to estimate the covariance areas observations, for which Judge et al. (1980) uses the term EGLS. For a first-order AR process, the estimates are often termed Prais-Winsten estimates. (p. 179)

Before considering some of the empirical evidence on the relationships considered, this study has to deal with the overlapping contracts issue. For example, in testing pricing efficiency, this study uses a futures price with a one-year contract and quarterly data. Then, this study would expect a priori that the error term would be serially correlated. This follows because when the number of observations are more frequent than the maturity length, the error term will not be independent of past forecast errors, but will instead follow a moving average process of order three. Thus, in any test of pricing efficiency, care must be taken in case of having the overlapping contracts issue.

4.10 Test of Rational Expectations Hypothesis

4.10.1. Unit Root Problem

A number of unit root tests have been suggested in the literature (Dickey and Fuller, 1979).

Let $$P_t = P_{t-1} + e_t, \tag{4.53}$$

where e_t is serially uncorrelated and $var(e_t) = \alpha_t^2$, and let $P_0 = 0$. Then, $P_t = \sum_{s=1}^{t} e_s$, that $var(P_t) = t\alpha_t^2$, which tends to infinity with t.

The term "unit root" refers to the unit coefficient on P_{t-1}. The statements "P_t has a unit root" and "P_t is integrated of order one" are equivalent.

This study used unit root tests introduced by Dickey and Fuller (1979). Suppose P_t can be described by the following equation:

$$P_t = \alpha + \beta t + \rho P_{t-1} + \lambda_1 \Delta P_{t-1} + e_t, \tag{4.54}$$

where $DP_{t-1} = P_{t-1} - P_{t-2}$. Using OLS,

$$P_t - P_{t-1} = \alpha + \beta t + (\rho - 1) P_{t-1} + \lambda_1 \Delta P_{t-1}, \tag{4.55}$$

and then the restricted regression

$$P_t - P_{t-1} = \alpha + \lambda_1 \Delta P_{t-1}. \tag{4.56}$$

Then, one calculates the standard F ratio to test whether the restrictions (β=0, ρ=1) hold.

4.10.2 Test of Unbiasedness: Direction of Change

Another emerging problem could be that the actual prices (P_t) and futures prices $(P^{f,t}_{t-4})$ may be non-stationary (unit roots) and, therefore, futures market efficiency should be tested using rates of change (direction of change).

$$P_t - P_{t-4} = a_1 + b_1 [P^{f,t}_{t-4} - P_{t-4}] + V_t. \qquad (4.57)$$

Thus, upon subtracting P_{t-4} from P_t and $P^{f,t}_{t-4}$, the following is obtained: Again, it is expected that $a_1 = 0$, $b_1 = 0$ and V is a white noise. This is the predicted direction of change.

The idea of testing by using rates of changes is similar to Fama and French's (1985) idea which is economic reasoning instead of statistic reasoning. Fama and French's search for the forecasting power in futures prices by regressing the realized change in the spot price $P_t - P_{t-4}$ against the basis $P^{f,t}_{t-4} - P_{t-4}$. Pt is the subsequent spot price, and $P^{f,t}_{t-4}$ is the futures price at time t to be observed at time t-4.

They indicate that the slope coefficient b_1 is positive which implies that the basis observed at t contains information about the change in the spot price. Also, Dominguez (1979) shows that using the change in the spot rate, rather than the level, constitutes a more stringent test of rational expectation.

$$P_t - P_{t-4} = a_o + b_o(P^{e,t}_{t-4}) - P_{t-4} + u_t. \tag{4.58}$$

Adding the current spot, $P_{(t-4)}$, to both sides of the equation (4.57) and rearranging the terms, the result is

$$P_t = a_o + b_o P^{f,t}_{t-4} + (1 - b_o)\, P_{t-4}. \tag{4.59}$$

In this case whether it is in the futures price or current spot rate that has more predictive power than each other.

By the same method, equation (4.58) becomes.

$$P_t = a_o + b_o P^{e,t}_{t-4} + (1 - b_o)\, P_{t-4}. \tag{4.60}$$

To include the current spot rate in the regression allows for observation to distinguish whether the current spot rate or the forecast actually has predictive power.

4.10.3 A Trading Rule Strategy

If a speculator in the live hog futures market believes that the actual or spot price will be higher than the presently quoted futures price, he will buy long. He will buy hog futures for delivery in 12 months at the presently quoted futures price. If his estimate is correct, he will make a profit since he will be able to sell the hogs at the market price on that date.

How does a speculator behave if he expects the spot market to be lower than the presently quoted futures price? In this case, he will sell short. The speculator then sells a contract for delivery in 12 months at the presently quoted price. Assume that his estimate of the actual futures/spot price is lower; then, he can buy the hogs at the price which is less than the futures price. Theoretically, cash will be approximately equal to futures at delivery time. However, he buys the hogs on that date and fulfills his contract making a profit. If his judgment had been wrong, and the market price had gone up, he would take a loss.

4.10.4 Cointegration Test

After establishing that the two series P_t and $P^{f,t}_{t-4}$ are both integrated of the first order, they are candidates for an equilibrium relationship. To determine whether the variables form a level relationship, the following cointegration regression is run:

$$P_t = a_1 + b_1 P^{f,t}_{t-1} + v_{1,t}. \tag{4.61}$$

If both variables, P_t and $P^{f,t}_{t-1}$, have orders of integration, I(1) or P_t and $P^{f,t}_{t-1}$ are unit roots, then, P_t and $P^{f,t}_{t-1}$ can form an equilibrium relationship because $(P_t - P^{f,t}_{t-1})$ is stationary. Being stationary requires that the series be non-explosive; as a difference equation it has to have stable roots.

The standard statistical information is not valid when the variables are nonstationary and regressions are shown to generate a spurious relationship among the variables.

4.11 Weak Information Efficiency

Unbiased forecasts satisfy one criterion for rationality. It is possible that predicted prices can show evidence of systematic bias yet can be characterized as weakly rational in the sense that the forecasts efficiently utilize all information contained in the history of prices. A rational forecast must pass the test of unbiasedness and efficiency.

To implement the efficiency test, forecast errors are calculated for each forecast horizon and used as a dependent variable. To test Weak Information Efficiency, the regression of forecast error $(P_t - P^{e,t}_{t-4})$ is run on the past actual prices $(P_{t-1}, P_{t-2}, P_{t-3}, \text{ and } P_{t-4})$.

4.12 Sufficient Orthogonality

The forecast must be weakly rational and must pass a more demanding test of sufficient orthogonality. That is, the forecast error cannot be correlated with any variable in the information set available at the time of prediction. In this case, this study ran a regression of forecast error ($P_t - P^{e,t}_{t-4}$) on the futures price ($P^{f,t}_{t-4}$) and cold storage (COT), protein cost (Pro), population (Pop), and sow farrowing (SF).

CHAPTER V

RESULTS AND INTERPRETATIONS

The models specified in Chapter IV,

Model I, equation numbers 4.22, 4.23, and 4.24

and Model II, equation numbers 4.47, 4.48, and 4.49,

were fitted using data from 1975, Qtr I to 1985, Qtr II. The empirical estimates of the parameters of Models I and II are presented in equations (5.1) through (5.6). The equations also exhibit the coefficients of determination R^2 and adjusted R^2, t-statistic, Durbin-Watson (DW) statistic, and root-mean square errors.

This study will estimate the model by recursive methods. Then this study will use the estimated model to forecast hog prices for four periods ahead in order to get the forecast price. This study forecasts outside sample hog prices from demand equations. Two models were used to forecast the hog price at the time t-4. Concurrently, the futures price at time t will be observed at time t-4. Consequently, this study will compare the forecast price between the two models, Models I and II, and hog futures markets. All results were compared by testing for unbiasedness using Ordinary Least Squares (OLS) and Generalized Least Squares (GLS) (AR1). GLS is a method to solve autocorrelation problems that recognizes the relationship among the residuals in some appropriate fashion. The direction of change will be applied to test for unbiasedness using GLS(AR1). When futures prices are used to test for unbiasedness of subsequent spot price, it is understood that this is the test for pricing efficiency in the futures market. However, another test for market efficiency is whether the participants in the futures market can earn above-normal profits as a result of the trading rules strategies. If the forecast price of each model does not reject the unbiasedness tests, then the Weak Information Efficiency and sufficient orthogonality tests (or sufficient rationality tests) must be performed in order for the forecast to be classified as the Rational Expectations Forecast.

This study carries out hypothesis tests on these equations by the t-test procedure using a 5% percent significance level. As depicted in equations (5.1) through (5.6), if the t estimate is greater than the t critical value, then that estimate becomes statistically significant. Mostly, each coefficient is statistically significant at the 5 percent level. Should this study discard a variable which is statistically insignificant? The answer is no, because those variables may have economic importance in the market model, even though they do not have acceptable statistical significance.

Many investigations, however, stop if they have a "good R^2" and sensible coefficients with "significant" t ratios. The problem is that a variety of combinations of t values and R^2 are possible. Leser and Geary (1968) provide the criterion whether the estimated regressions are reliable. They characterize the possible combinations of significance and/or insignificant groups of R^2 and t. They list the following possible outcomes.

(1) R^2 and all t ratios are significant;

(2) R^2 and some t ratios are significant;

(3) R^2 is significant; all t ratios are insignificant;

(4) All t ratios are significant, but R^2 is not;

(5) Some t ratios are significant but R^2 is not; and

(6) All t ratios as well as R^2 are significant.

Cases (1) and (6) present no problem. Case (2) is very common, particularly with a large number of explanatory variables, and the only problem is to decide which of the non-significant variables, if any, to exclude from the equation in order to get a more parsimonious model without losing explanatory power.

Epte (1990, p. 197) described the situation of case (3). This is a typical manifestation of the multicollinearity problem. In the presence of a high degree of intercorrelations among the explanatory variables, none of their individual coefficients can be reliably estimated even though as a group they have good explanatory power.

Case (4) occurs rarely in practice. Leser and Geary consider case (5) as the most problematic.

In this study, the results generally fall into case (2) which is common, R^2 and some t-ratios are significant. The usual practice is to drop some of the significant variables to obtain a more parsimonious model without losing explanatory power. Some rule has to be followed in deciding which variables should be dropped. However, Williams (1959, pp. 4-7) indicates that the significant tests should not be used mechanically to exclude a variable from a regression equation when the sign (+ or -) of the coefficient is correct, based on a priori considerations.

5.1 Economic Interpretation of Regression Results

All signs of the important variable in Models I-II (see Table 5.1 for Model 1 and Table 5.2 for Model II) are consistent with a priori expectations. The regression results for each equation are discussed below.

The coefficient of expected price of $\{E_{t-4}(P_t|I_{t-4}) = P_t\}$ in Model I is negative and significant. When the predicted price at quarter t increases one dollar per hundredweight, the size of the pig crop at quarter t-2 would decrease by 312,070 head (312.070 x 1,000), where -312.07 is the coefficient of $E_{t-4}(P_t|I_{t-4})$ (see Table 5.1, equation 5.1). The evidence presented in this study, as explained below, substantiates these economists' finding [Clower et al. (1988), Hayes and Schmitz (1987), Marsh (1984), Muth (1961), and Newberry and Stiglitz (1981)]. There is a negative relationship between the

Table 5.1 Model I: Using $E_{t-4}(P_t|I_{t-4}) = P_t$

Type of equation	Equation	Equation Number
Pig-crop equation	$Pig_{t-2} = 32717 - 312.07E_{t-4}(P_t\|I_{t-4}) + .25\,Pig_{t-4} - 1965.28PC_{t-4}$ t values = (5.79) (-2.23) (1.71) (-1.92) $-390.51IR_{t-4} - 1294.00D_1 - 3428.68D_2 - 5131.57D_3$ (-1.48) (-2.27) (-5.08) (-9.37) $-102.18(Time - 2)$ (-1.91) $R^2 = .91, \bar{R}^2 = .87, DW = 1.745$	(5.1)
Supply equation	$Q_t = -3207.66 + .94Pig_{t-2} + 685.09D_1 + 2415.70D_2$ t value = (-1.265) (9.87) (1.46) (4.94) $+ 2421.81D_3 + 63.69(Time)$ (3.70) (3.65) $R^2 = .87, \bar{R}^2 = .84, DW = 1.270.$	(5.2)
Demand equation	$P_t = 43.8 - .002Q_t + .002DPI_t + 1.22PBR_t + .12PBF_t$ t values = (1.30) (-5.06) (.94) (.61) (1.80) $-2.19WPC_t - 1.93D_1 - .72D_2 - 3.65D_3 - .11Time$ (-.19) (-2.02) (-.79) (-3.00) (-1.01) $R^2 = .87, \bar{R}^2 = .82, DW = 1.49, RMSE = 1.61.$	(5.3)

Table 5.2. Model II: Using $E_{t-4}(P_t|I_{t-4}) - E_{t-5}(P_{t-1}|I_{t-5})$

Type of equation	Equation	Equation Number
Pig-crop equation	$Pig_{t-2} = 38638 + 235.61EXPCH + .07Pig_{t-4} - 1.55\,VP_{t-4} - 1293.80PC_{t-4}$ t values = (8.22) (2.29) (-.57) (-.33) (-1.16) $-3874.84VPC_{t-4} - 526.41IR_{t-4} - 3713.91WF_{t-4}$ (-1.11) (-2.35) (-3.02) $2310.94D_1 - 3280.39D_2 - 6669.20D_3 + 69.234(Time - 2)$ (-4.18) (-6.45) (-12.32) (2.31) $R^2 = .93, \bar{R}^2 = .90, DW = 1.913.$	(5.4)
Supply equation	$Q_t = -2143.45 + .90Pig_{t-2} + 560.65D_1 + 2284.003D_2$ t value = (-.85) (9.79) (1.23) (4.82) $+ 2219.23D_3 + 59.09(Time)$ (3.53) (3.51) $R^2 = .84, \bar{R}^2 = .81, DW = 1.704.$	(5.5)
Demand equation	$P_t = 37.28 - .0016Q_t + .0013DPI_t + .17PBR_t + .14PBF_t$ t values = (.94) (-4.22) (.24) (.74) (1.61) $-.83WPC_t - 2.162D_1 - 1.11D_2 - 3.81D_3 - .07Time$ (-.07) (-2.05) (-1.15) (-2.65) (-.56) $R^2 = .84, \bar{R}^2 = .77, DW = 1.48, RMSE = 1.75.$	(5.6)

producers' price expectations at time t, observed at time t-4, and pig crop at time t-2. In the analysis, assuming that the cobweb exists, a rational person will produce along the demand curve. The actual price at time t falls on the demand curve. The actual price has a positive relationship with the producers' price expectation at time t, observed at time t-4. Therefore, there is a negative relationship between pig crops at time t-2 and producers' price expectations at time t, observed at time t-4.

Marsh (1984) found the negative relationship between the number of barrows and gilts slaughtered and price of barrows and gilts at the same quarter. Marsh found that for every dollar per hundredweight increase in the price of barrows and gilts, the number of barrows and gilts slaughtered was reduced by 227,000 head (227 x 1,000). In Model I of this study, when expected price increased one dollar per hundredweight, the producers would produce less hogs, about 312,000 head, while Marsh's estimation is about 227,000 head.

The coefficient of EPCH (expected change of hog price), Model II, is positive and significant. This model is the long-run analysis because the producers form the price expectation for more than a year, from time t-5 to time t, which is six quarters. When the expectations change one dollar per hundredweight, the producers would put pigs, 325,610 head (325.61 x 1000), into the confinement house.

The hog producer is longsuffering because of the profit loss. Due to the price fluctuation, they consider the uncertainty of the future price to be a risk. To produce more they must capture the positive trend of price expectations. In order to produce a larger pig crop at time t-2, the producers have to capture the positive trend of price expectations for four quarters ahead from their observation at time t-4 and time t-5.

In Models I and II, the negative coefficients attached to the price of corn at quarter t-4 suggest that price of corn at the time of making a decision has a negative impact on pig crop for two quarters ahead.

Model II included the price risk of hogs and the price risk of corn in the consideration. Both variables have negative relationships with the pig crop. However, the coefficients are insignificant. If the price risk of hogs increases by one dollar per hundredweight, there would be less pigs in the confinement house, about 1.55 thousand head. When the price risk of corn increases one cent per bushel, the hog producers would put less pigs in the confinement house, about 38.74 thousand head.

5.1.1. Pig Crop Adjustment

If λ (the coefficient adjustment) = 1, this means that the actual change of pig crop is equal to the desired change of pig crop. The coefficient adjustment can be derived from the estimated coefficient (1-λ) of PIG_{t-4} (pig crop at quarter t-4).

The coefficient adjustment of the pig crop for Models I and II are equal to .75 and .93, respectively. The actual pig crop adjustment in Model II is almost adjusted completely to the desired pig crop compared to Model I.

5.1.2 The Supply Equation

In Models I and II, all of the coefficients of the pig crop at quarter t-2 are positive and significant. The estimated coefficients have acceptable signs and magnitudes. There is almost a one-to-one relationship between the pig crop at quarter t-2 and quantity of hog slaughter at quarter t.

5.1.3 The Demand Equation

All the estimated coefficients have acceptable signs. The signs of the estimated coefficients of Q_t and WPC_t are negative and of DPI_t, PBR_t, and PBF_t are positive. There are some seasonal factors operating in the first and third quarters for Models I and II.

5.2 Ex Ante Forecast of Explanatory Variables

With the data from 1975 Qtr I through 1985 Qtr II, the estimated AR models of PBR_t, PBF_t, and WPC_t appear in Tables 5.3, 5.4, and 5.5.

Table 5.3 Test for the order of Autoregression in Model PBR_t

Order of Auto-regression	Equation	Hypothesis Test /Results	Equation Number
AR(3)	$PBR_t = .97\ PBR_{t-1} + .11\ PBR_{t-2} - .09\ PBR_{t-3}$ (SEE) = (.17) (.24) (-.17)	$\frac{\Phi_3}{S_3} = \frac{-.09}{-.17} = .53.$ /The null hypothesis that $\Phi_3 = 0$ is not rejected.*	(5.7)
AR(2)	$PBR_t = .96\ PBR_{t-1} + .03\ PBR_{t-2}$ (SEE) = (.17) (.17)	$\frac{\Phi_2}{S_2} = \frac{.03}{.17} = .18.$ /The null hypothesis that $\Phi_2 = 0$ is not rejected.*	(5.8)
AR(1)	$PBR_t = .99\ PBR_{t-1}$ (SEE) = (.04)	$\frac{\Phi_1}{S_1} = \frac{.99}{.04} = 24.75.$ / The null hypothesis that $\Phi_1 = 0$ is rejected.*	(5.9)

* The AR models use a 5% level of significance.

Table 5.4 Test for the order of Autoregression in Model PBFt

Order of Auto-regression	Equation	Hypothesis Test /Results	Equation Number
AR(3)	$PBF_t = .97\ PBF_{t-1} + .15\ PBF_{t-2} - .13\ PBF$ (SEE) = (.17) (.24) (-.17)	$\frac{\Phi_3}{S_3} = \frac{-.13}{-.17} = .76.$ /The null hypothesis that $\Phi_3 = 0$ is not rejected.*	(5.10)
AR(2)	$PBF_t = .97\ PBF_{t-1} + .02\ PBF_{t-2}$ (SEE) = (.17) (.17)	$\frac{\Phi_2}{S_2} = \frac{.02}{.17} = .12.$ /The null hypothesis that $\Phi_2 = 0$ is not rejected.*	(5.11)
AR(1)	$PBF_t = .99\ PBF_{t-1}$ (SEE) = (.03)	$\frac{\Phi_1}{S_1} = \frac{.99}{.03} = 33.00.$ / The null hypothesis that $\Phi_1 = 0$ is rejected.*	(5.12)

* The AR models use a 5% level of significance.

Table 5.5 Test for the order of Autoregression in Model WPC_t

Order of Auto-regression	Equation	Hypothesis Test /Results	Equation Number
AR(3)	$WPC_t = 1.01\ WPC_{t-1} + .02\ WPC_{t-2} - .01\ WPC_{t-3}$ (SEE) = (.17) (.24) (-.17)	$\frac{\Phi_3}{S_3} = \frac{-.01}{-.17} = .06.$ /The null hypothesis that $\Phi_3 = 0$ is not rejected.*	(5.13)
AR(2)	$WPC_t = 1.01\ WPC_{t-1} + .01\ WPC_{t-2}$ (SEE) = (.17) (.17)	$\frac{\Phi_2}{S_2} = \frac{.01}{.17} = .06.$ /The null hypothesis that $\Phi_2 = 0$ is not rejected.*	(5.14)
AR(1)	$WPC_t = .99\ WPC_{t-1}$ (SEE) = (.03)	$\frac{\Phi_1}{S_1} = \frac{.99}{.03} = 33.00.$ / The null hypothesis that $\Phi_1 = 0$ is rejected.*	(5.15)

* The AR models use a 5% level of significance.

The null hypothesis, for PBR_t, PBF_t, and WPC_t , that $\Phi_1=0$ is rejected. Therefore, the first-order autoregressive model will be used to forecast the series of PBR_t, PBF_t, and WPC_t.

To forecast the Consumer Price Index (CPI_t) and disposable personal income (DPI_t),the regression-autoregression pair of models (see equations 4.28 and 4.29) will be used. However, there is no seasonal variation in this estimation. For the time period 1975, Qtr I through 1985, Qtr II, the consumer price index and disposable income are as follows:

Estimation of CPI_t:

$$CPI_t = 1.46 + .04 \text{ Time}$$
$$\text{t-values} = (27.91)\ (20.34) \tag{5.16}$$

$$U_t = -.91 U_{t-1} \tag{5.17}$$

When U is a non-autocorrelated error term.

$$R^2 = .92, DW = .74$$

Estimation of DPI_t:

$$DPI_t = 4516.07 + 158.53 \text{ Time}$$
$$\text{t-values} = (21.65) \quad (16.88) \tag{5.18}$$

$$U_t = -.59 U_{t-1}$$
$$R^2 = .89,\ DW = 1.70 \tag{5.19}$$

Estimation of hog quantity supplied (Q_t):

From the time period, 1975 Qtr. I through 1985, Qtr.II, the estimated regression equation Q_t is:

$$Qt = 8731.13 + .58Pig_{t-4} - 403.99D_1 - 2134.34D_2 -$$

$$\text{t-values} = (3.85) \quad (5.07) \quad (-.58) \quad (-2.85)$$

$$3067.13D_3 + 40.93Time \tag{5.20}$$

$$(1.39) \quad (-4.61)$$

$$R^2 = .74, DW = .71$$

All coefficients of the Demand equation come from the estimation from the structural model by the recursive method. Therefore, P_t is a function of Q_t, DPI_t, PBR_t, PBF_t, WPC_t, D_1, D_2, D_3, and Time, respectively. Hence, Q_t, DPI_t, PBR_t, PBF_t, and WPC_t, have to be estimated; then, the resulting estimates are inserted into the demand equation to get $\hat{P}_t$ (predicted price). Then, this study considers adding $\{\Delta_{t-4} *(\rho_{t-4})^4\}$, which is the serially correlated error at time t, t-1, t-2, and t-3, to $\hat{P}_t$ to get the forecast price $P^{e,t}_{t-4}$. ρ_{t-4} is the first order correlation from the demand equation at time t-4 and Δ_{t-4} is an error forecast at time t-4, then the forecast $P^{e,t}_{t-4}$ is obtained. P_t is the actual price of hog at time t. $P^{e,t}_{t-4}$ is the forecast price of hog at time t observed at time t-4. In this study, there are three forecast prices. Models I and II produce two forecast prices, respectively. The live hog futures market creates futures price $P^{f,t}_{t-4}$ at time t observed at t-4. Table 5.6 compares among actual price, forecast price, and futures price. If forecast price, $P^{e,t}_{t-4}$ (or $P^{f,t}_{t-4}$) is an unbiased prediction of the actual price, P_t, then the estimate of the slope should be one. An error term is assumed to be from a series of independent and identically distributed normal random variables in the zero mean.

However, if unit roots are present in both dependent and independent variables in the regression, a violation of the underlying assumption of OLS occurs. Thus, a standard inference procedure cannot be applied to bias regression estimated through OLS because F-statistics calculated to test the null hypothesis of unbiasedness (intercept = 0, slope = 1) are not distributed as a standard F-distribution.

Table 5.6: Actual Price of Hogs (P_t), Forecast Prices (out of sample) ($P_{t-4}^{e,t}$) and Futures Price ($P_{t-4}^{f,t}$)

Year Qtr	P_t	$P_{t-4}^{e,t}$ (Model I)	$P_{t-4}^{e,t}$ (Model II)	$P_{t-4}^{f,t}$
1986 Qtr				
II	42.40	48.89	50.70	45.00
III	59.63	48.19	50.20	46.20
IV	55.61	44.19	46.80	39.95
1987 Qtr				
I	49.18	48.61	48.17	41.10
II	51.88	49.63	49.80	38.70
III	61.09	50.48	55.04	45.87
IV	48.04	53.21	52.53	43.50
1988 Qtr				
I	44.19	47.91	46.39	39.40
II	44.21	48.34	51.88	37.75
III	46.58	58.85	61.09	43.50
IV	38.81	42.96	48.04	40.25
1989 Qtr				
I	41.13	38.85	44.19	44.63
II	39.76	35.01	44.21	41.55
III	46.67	46.48	46.58	53.55
IV	47.75	42.18	38.81	45.00
1990 Qtr				
I	48.59	39.19	41.13	45.40
II	56.07	37.21	40.26	44.25

5.3 Test of Rational Expectations Hypothesis

5.3.1 Test of Unit Root of Hog Cash (P_t) and Futures Price ($P^{f,t}_{t-4}$)

By using a Dickey-Fuller (1981) unit root test on the hog price and live hog futures price from periods 1975, Qtr I through 1985, Qtr II, and 1975, Qtr I through 1990, Qtr II.

5.3.1.1 Hog Cash Price

For 1975, Qtr I through 1985, Qtr II, the unrestricted and restricted regressions are as follows:

Unrestricted Regression

$$P_t - P_{t-1} = 20.69 + .02\ \text{Time} - .46\ P_{t-1} + .13\ \Delta P_{t-1},$$

where $\Delta P_{t-1} = P_{t-1} - P_{t-2}$ and sum squared residuals (5.21)

$(SSR_{UR}) = 1039.1042.$

Restricted Regression

$$P_t - P_{t-1} = .03 - .10\ \Delta P_{t-1}, \tag{5.22}$$

where the sum of squared residuals $SSR_R = 1310.9876$. The F-ratio can be calculated by

$$F = (N - K)(SSR_R - SSR_{UR}) / q(SSQ_{UR})$$

where SSR_R and SSR_{UR} are the sum of squared residuals of the unrestricted and restricted regression, respectively. N is the number of observations, K is the number of estimated parameters, and q is the number of parameter

$$F = \frac{(42-4)(1310.99-1039.10)}{(2)(1039.10)} = 4.97.$$

restrictions.

The critical F-value by Dickey and Fuller (1981) at the 5% level is equal to 6.73. Thus, we cannot reject the hypothesis of a random walk for hog prices.

For from 1975, Qtr I through 1990, Qtr II of hog price, the unrestricted and restricted regression are as follows.

The unrestricted regression is:

$$P_t - P_{t-1} = 21.81 + .03\ \text{Time} - .48\ P_{t-1} + .07\ \Delta P_{t-1}$$
$$SSR_{UR} = 1667.27 \tag{5.23}$$

The restricted regression is:

$$P_t - P_{t-1} = .26 - .17\ \Delta P_{t-1}$$
$$SSR_t = 2092.32 \tag{5.24}$$

The computed F-ratio is 7.39.

The critical F value at the 5% (and 2.5%) level is equal to 6.73 (and 7.81). The hypothesis of a random walk at 5% level can be rejected, from

1975 Qtr I to 1990 Qtr II, implying that there is the mean reversion in the hog price. However, the hypothesis of a random walk of hog prices at 2.5% level cannot be rejected.

5.3.1.2 Futures Price Test

From 1975 Qtr I to 1985 Qtr II, the unrestricted and restricted regression are as follows.

The unrestricted regression is:

$$P_t^f - P_{t-1}^f = 21.17 + .154\ \text{Time} - .54\ P_{t-1}^f + .17\ \Delta P_{t-1}^f$$

$$SSR_{UR} = 1106.54 \tag{5.25}$$

The unrestricted regression is:

$$P_t^f - P_{t-1}^f = .36 - .42\ \Delta P_{t-1}^f,$$

$$SSR_R = 1364.59. \tag{5.26}$$

The computed F-ratio is 4.43 for 1975, Qtr I through 1985 Qtr II. In comparing the computed value F (6.73 at the 5% level), the null hypothesis of random walk cannot be rejected.

For 1975, Qtr I through 1990, Qtr II, the unrestricted and restricted regression are as follows.

The unrestricted regression is:

$$P^f_t - P^f_{t-1} = 17.82 + .02\ \text{Time} - .41\ P^f_{t-1} - .24\ \Delta P^f_{t-1}$$

$$SSR_R = 1364.59. \tag{5.27}$$

The restricted regression is:

$$P^f_t - P^f_{t-1} = .09\ \text{Time} - .44\ \Delta P^f_{t-1},$$

$$SSR_R = 1748.98. \tag{5.28}$$

The computed F-ratio is 4.8.

In comparing the computed F value to the critical F value, the null hypothesis of random walk of the live hog futures from 1975 Qtr I to 1990 Qtr II cannot be rejected.

The result of the unit root tests, from 1975 Qtr I to 1985 Qtr II, conclude that both hog price and futures price are random walk at 5% level. Also, from 1975 Qtr I to 1990 Qtr II, the unit root test indicates that there is a random walk in the live hog futures price. From 1975 Qtr I to 1990 Qtr II, the unit root test of hog price indicates that there is no random walk at 5 percent level. However Pindyck and Robinfeld (1991) state that a failure to reject (especially at a high significance level) is only weak evidence in favor of the random walk hypothesis (p. 462). Therefore the result of the unit root tests conclude that both hog and futures price are unit roots.

Elam and Dixon (1988) found that the financial price series are generally not stationary and they contain a unit root. They consider that the standard F-test of the hypothesis $a_0 = 0$ and $b_0 = 0$ (equation 2.34) is not appropriate. Since the stochastic process of generating actual and futures prices is nonstationary, therefore, forward marketing efficiency should be tested using rate of change or direction of change. Using the change rather than the level can constitute a more rigorous test of unbiasedness of the regression coefficients. This idea is consistent with the search for the predictive power in futures prices of Fama and French (1985).

This study attempts to avoid the nonstationary problem by considering the following equations.

Equation (4.57): $(P_t - P_{t-4}) = a_1 + b_1 (P^{f,t}_{t-4} - P_{t-4}) + v_t$

and Equation (4.58): $(P_t - P_{t-4}) = a_0 + b_0 (P^{e,t}_{t-4} - P_{t-4}) + u_t$.

Then the test is whether $a_1 = 0$, $b_1 = 1$ (in case of testing of unbiasedness of futures price or pricing efficiency test).

5.3.2 Test for Unbiasedness

5.3.2.1 Regression Results: Test for Unbiasedness of Direction of Change for Models I-II's Forecast Prices

Model I: $E_{t-4}(P_t | I_{t-4}) = P_t$

$$(P_t - P_{t-4}) = 2.16 + .43\,(P^{e,t}_{t-4} - P_{t-4}) \qquad (5.29)$$

t values = (7.67) (1.05)

Time Span: 1986, Qtr II through 1990, Qtr II

R^2 = .07 Total R^2 = .39
RMSE = 7.50
DW = 1.22

DW Statistic: (5% Significance point of d_L and d_u)
d_L = 1.106 and d_u = 1.371

F-Statistic (for intercept = 0, and slope = 1) = 2.19
$F_{.05}(2,14) = 3.74$.

Equation can be modified as:

$$P_t = 2.16 + .43P^{e,t}_{t-4} + .57P_{t-4}. \quad (5.30)$$

Because the F-statistic is less than $F_{.05}(2,14)$, then the hypothesis of no bias is not rejected. The DW statistic lies between d_L and d_u. The test is inconclusive. The comparison of the coefficients, .43 and .57, indicates that the current spot price, P_{t-4}, has more predictive power than the price forecast, $P^{e,t}_{t-4}$.

<u>Model II</u>: $E_{t-4}(P_t | I_{t-4}) - E_{t-5}(P_{t-1} | I_{t-5})$

$$(P_t - P_{t-4}) = 1.08 + .84\,(P^{e,t}_{t-4} - P_{t-4}) \quad (5.31)$$
t values = (.51) (2.4)

Time Span: 1986, Qtr II through 1990, Qtr II

R^2 = .29 Total R^2 = .44
RMSE = 7.25
D-W = 1.28

D - W Statistic: (5% Significance point of d_L and d_u)
$d_L = 1.106$ and $d_u = 1.371$

F - Statistic (for intercept = 0, and slope = 1) = .27
$F_{.05}(2,14) = 3.74$.

Equation can be modified as:

$$P_t = 1.08 + .84P^{e,t}_{t-4} + .16P_{t-4}. \tag{5.32}$$

Because the F-statistic is less than $F_{.05}(2,14)$, then the hypothesis of no bias is not rejected. The DW statistic lies between d_L and d_u. The test is inconclusive. The comparison of the coefficient, .84 and .16, indicates that the forecast price, $P^{e,t}_{t-4}$, has more predictive power than the current spot price, P_{t-4}.

5.3.2.2 Regression Results: Test for Unbiasedness of Direction of Change for Futures Market {AR(1)}

$$(Pt - P_{t-4}) = 4.14 + .71\,(P^{f,t}_{t-4} - P_{t-4}) \tag{5.33}$$
t values = (1.43) (2.51)

Time Span: 1986, Qtr II through 1990, Qtr II

R^2 = .31 Total R^2 = .59
RMSE = 6.16
DW = 1.71

DW Statistic: (5% Significance point of d_L and d_u)
$d_L = 1.106$ and $d_u = 1.371$

F - Statistic (for intercept = 0, and slope = 1) = 6.96
$F_{.05}(2,14) = 3.74.$

Equation can be modified as:

$$P_t = 4.14 + .71P^{f,t}_{t-4} + .29P_{t-4}. \tag{5.34}$$

Because the F-statistic is greater than $F_{.05}(2,14)$, then the hypothesis of no bias is rejected. The DW statistic lies above d_u. The test results conclude that there is no evidence of a positive error autocorrelation of order 1. It compares the coefficients .71 and .29 and indicates that the futures price time t observed at time t-4 has more predictive power than the hog price at time t-4.

From the equation (4.57), $P_t - P_{t-4} = a_1 + b_1[P^{f,t}_{t-4} - P_{t-4}] + v_t$

If $a_1=0$ and $b_1 = 1$ by the joint-F test, then $P_t - P^{f,t}_{t-4} = v_t$. Because $P_t - P^{f,t}_{t-4} = v_t$ = random errors, thus there is no arbitrage opportunity. As a result, the trading rule cannot be applied. Consequently, there is pricing efficiency in the futures market.

Assuming that $a_1 > 0$, and $0 < b_1 < 1$, then

$$P_t = a_1 + b_1(P^{f,t}_{t-4}) + (1 - b_1)P_{t-4} + v_t.$$

Therefore, $\qquad P_t - b_1(P^{f,t}_{t-4}) > 0$

Implying that $\qquad P_t \neq (P^{f,t}_{t-4})$, unless $b_1 = 1$.

Therefore, there is arbitrage opportunity in the futures market. The trading rule can be applied. As a result, this futures market has pricing inefficiency.

In the hog futures market, the hypothesis of no bias is rejected; therefore, the intercept $(a_1) = 4.14$ and slope $(b_1) = .71$

Thus, $$P_t = 4.14 + .71\, P^{f,t}_{t-4} + .29 P_{t-4}.$$

Then, $$P_t - .71\, P^{f,t}_{t-4} = 4.14 + .29 P_{t-4}.$$

Implying that $$P_t - .71\, P^{f,t}_{t-4} > 0$$

Therefore, $$P_t \neq P^{f,t}_{t-4}.$$

This result concludes that the hog futures market has arbitrage opportunity. As a consequence, the market has pricing inefficiency.

The slope estimate $[b_1 = .71]$ is the risk minimizing hedge ratio. This estimate result from equation (5.33), suggests selling 71 percent of hog production in the futures market. If the hedge works, the risk of the combined cash/futures positions should be less than the cash position alone. Therefore, the variance of income fluctuations can be reduced by using the risk minimizing hedge ratio. This slope $b_1 = .71$, should also reduce the risk minimizing hedge ratio adjusting for autocorrelation in the residuals of a price level regression.

Each model, I and II, shows unbiasedness of forecasting implying that Models I and II outperform the futures price forecast. Evidence that slope is reliably positive for Models I and II means that the predicted change (and futures price change) observed at time t-4 has power to predict the spot price change to be observed at time t-4.

Each model, I and II, contains in the inconclusive range of testing of autocorrelation at 5% significance. The Model of Hog Futures shows biasedness, but no serially correlation. The RMSE statistic, which is the measure of the dispersion of forecast errors, shows that futures price has the least RMSE compared to any other model (Models I and II).

By comparison between coefficients of price forecast and current price, it shows that forecast price $P^{e,t}_{t-4}$ and futures price, $P^{f,t}_{t-4}$ have more predictive power than current price (P_{t-4}).

5.3.3 A Trading Rule Strategy

If a speculator, using fundamentals to trade in the live hog futures market believes that the actual or spot price will be higher than the presently quoted futures price, he will buy long. He will buy hog futures for delivery in 12 months at the presently quoted futures price. If his estimate is correct, he will make a profit since he will be able to sell the hogs at the market price on that date.

How does a speculator behave if he expects the spot market to be lower than the presently quoted futures price? In this case, he will sell short. The speculator then sells a contract for delivery in 12 months at the presently quoted price. Assume that his estimate of the actual future market is correct, and on the date of delivery, the futures/spot price is lower; then, he can buy the hogs at the price which is less than the futures price. Theoretically, cash price will be approximately equal to futures price at delivery time. However, he buys the hogs on that date and fulfills his contract making a profit. If his judgment had been wrong, and the market price had gone up, he would take a loss.

The advantage of the trading rule approach is that it allows quantification of the departure from efficiency uncovered by the regression analysis.

The trading strategy is as follows. If $P^{e,t}_{t-4}$ is greater than $P^{f,t}_{t-4}$, then buy futures. On the contrary, if $P^{e,t}_{t-4}$ is less than $P^{f,t}_{t-4}$, then sell futures.

The results from the trading strategies for Model I and II are shown in Figures 5.1 and 5.2, respectively. The forecast prices that are being generated from Models I and II, which appear in Tables 5.7-5.8 make the promising profit returns of $1270.53 and $1207.35 per contract.

The models which do not reject the null hypothesis of the joint-F test, Model I and II, can earn a large amount of profit from its price forecast.

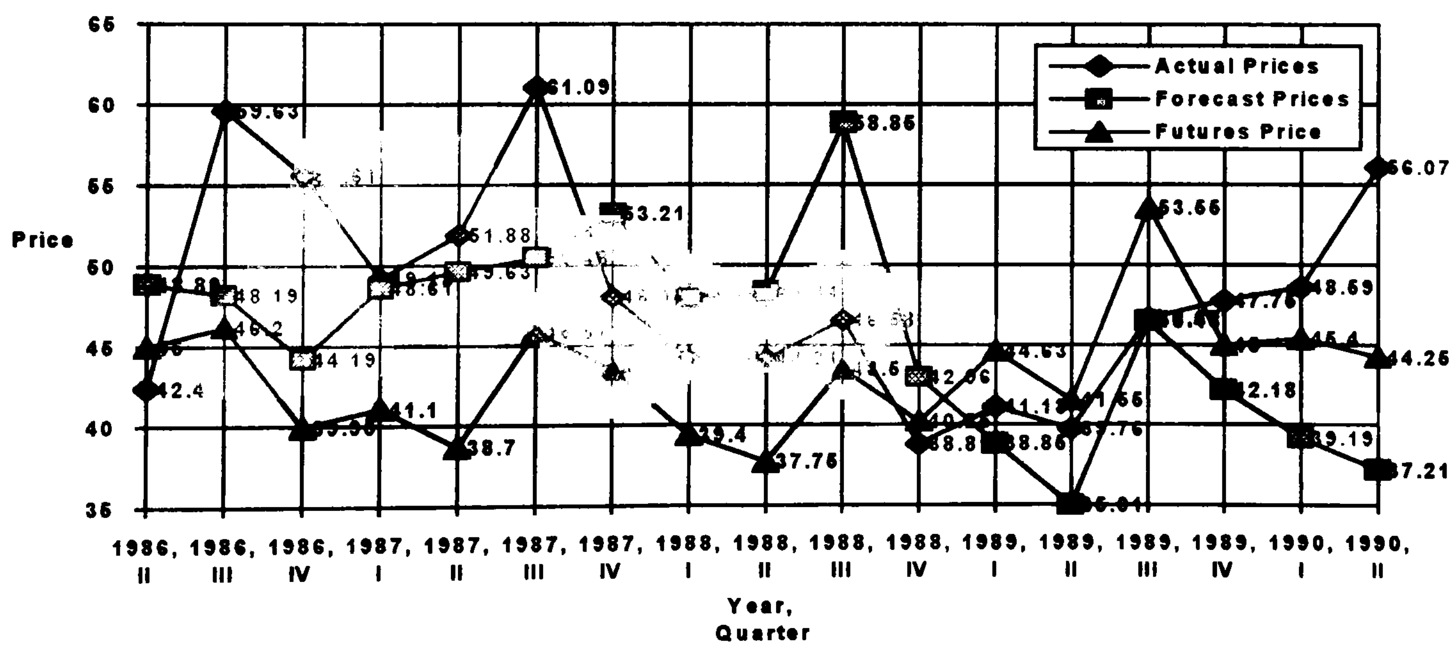


Figure 5.1. Actual Prices (P_t), Forecast Prices ($P^{e,t}_{t-4}$), and Live Hog Futures Prices ($P^{f,t}_{t-4}$), 1986, Qtr. II -- 1990, Qtr II, (Model I)

Table 5.7. Arbitrage Opportunities for Model I's Forecast Prices

Year, Qtr	Actual Price P_t (\$/cwt)	Futures Price $P^{f,t}_{t-4}$ (\$/cwt)	Forecast Price $P^{e,t}_{t-4}$ (\$/cwt)	Profit If $P^{e,t}_{t-4} >$ $P^{f,t}_{t-4}$ buy futures (\$/cwt)	Profit If $P^{e,t}_{t-4} <$ $P^{f,t}_{t-4}$ sell futures (\$/cwt)
1986					
Qtr II	42.40	45.00	48.89	-2.6	
Qtr III	59.63	46.20	48.19	+13.43	
Qtr IV	55.61	39.95	44.19	+15.66	
1987					
Qtr I	49.18	41.10	48.61	+8.08	
Qtr II	51.88	38.70	49.63	+13.18	
Qtr III	61.09	45.81	50.48	+15.22	
Qtr IV	48.04	43.50	53.21	+4.54	
1988					
Qtr I	44.19	34.40	47.91	+4.79	
Qtr II	44.21	37.75	48.34	+6.46	
Qtr III	46.58	43.50	58.85	+3.08	
Qtr IV	38.81	40.25	42.96	-1.44	
1989					
Qtr I	41.13	44.63	38.85		+3.50
Qtr II	39.76	41.55	35.01		+1.79
Qtr III	46.67	53.55	46.48		+6.88
Qtr IV	47.75	45.00	42.18		-2.75
1990					
Qtr I	48.59	45.40	39.19		-3.19
Qtr II	56.07	44.25	37.21		-11.82

Returns for 17 contracts = \$ 300(74.83)
Profit per contract = [300(74.83)/17] - 50 = \$1270.53

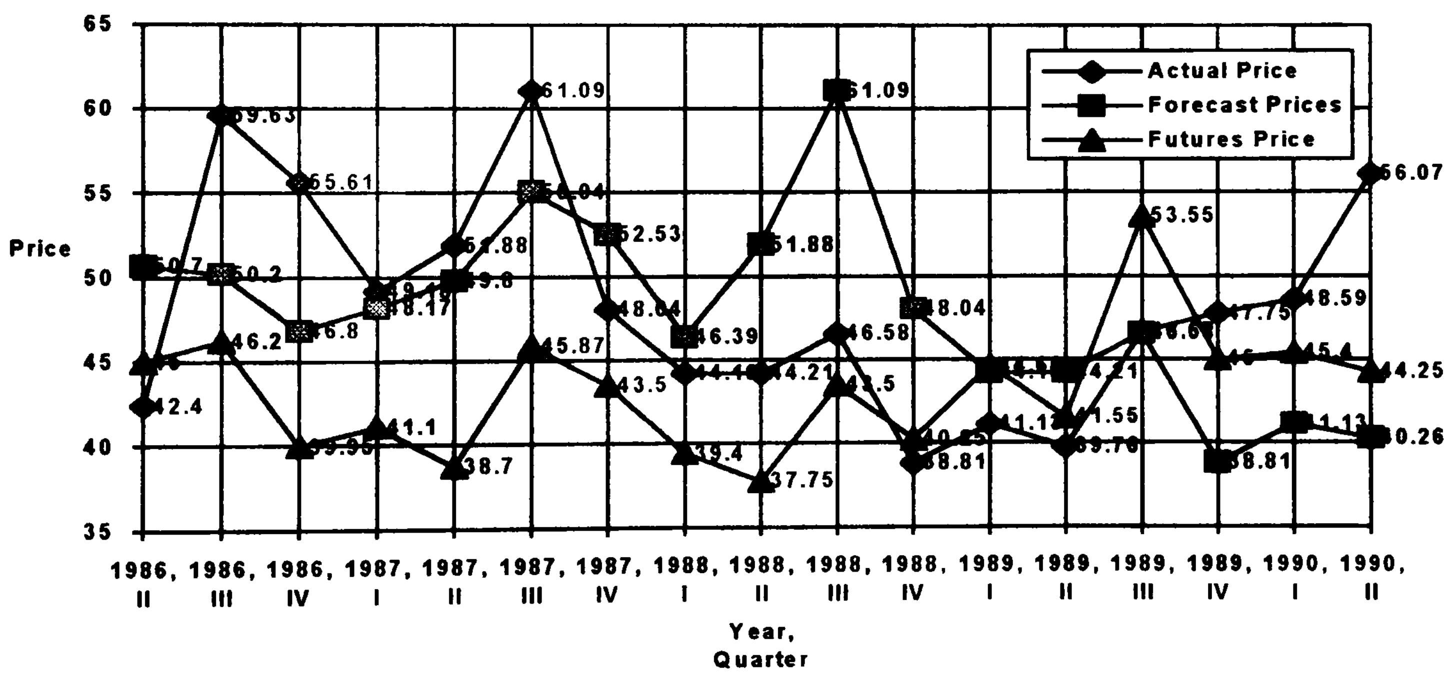


Figure 5.2. Actual Prices (P_t), Forecast Prices ($P^{e,t}_{t-4}$), and Live Hog Futures Prices ($P^{f,t}_{t-4}$), 1986, Qtr. II -- 1990, Qtr II, (Model II)

Table 5.8. Arbitrage Opportunities for Model II's Forecast Prices

Year, Qtr	Actual Price P_t (\$/cwt)	Futures Price $P^{f,t}_{t-4}$ (\$/cwt)	Forecast Price $P^{e,t}_{t-4}$ (\$/cwt)	Profit If $P^{e,t}_{t-4} > P^{f,t}_{t-4}$ buy futures (\$/cwt)	Profit If $P^{e,t}_{t-4} < P^{f,t}_{t-4}$ sell futures (\$/cwt)
1986					
Qtr II	42.40	45.00	50.70	-2.6	
Qtr III	59.63	46.20	50.20	+13.43	
Qtr IV	55.61	39.95	46.80	+15.66	
1987					
Qtr I	49.18	41.10	48.17	+8.08	
Qtr II	51.88	38.70	49.80	+13.18	
Qtr III	61.09	45.81	55.04	+15.28	
Qtr IV	48.04	43.50	52.53	+4.54	
1988					
Qtr I	44.19	39.40	46.39	+4.79	
Qtr II	44.21	37.75	51.88	+6.46	
Qtr III	46.58	43.50	61.09	+3.08	
Qtr IV	38.81	40.25	48.04	-1.44	
1989					
Qtr I	41.13	44.63	44.19		+3.50
Qtr II	39.76	41.55	44.21	-1.79	
Qtr III	46.67	53.55	46.58		+6.88
Qtr IV	47.75	45.00	38.81		-2.75
1990					
Qtr I	48.59	45.40	41.13		-3.19
Qtr II	56.07	44.25	40.26		-11.82

Return for 17 contracts = \$300(71.25)
Profit per contract = [300(71.25)/17] - 50 = \$1207.35

Therefore, during the period studied, 1986, Qtr II through 1990, Qtr II, the hog futures market is an inefficient market. Under these circumstances, a rising trend in cash prices is the mechanism that rewards long speculation. The overall generalization from the data investigated in this study is that the futures prices is a biased estimate of the subsequent spot price.

If a commodity is expected to be in over (under) supply because of a sharp decrease (increase) in corn prices, speculators will attempt to sell (buy) futures contracts with the expectations of buying (selling) them later at higher (lower) prices. The shrinking (expanding) demand will cause prices of contracts to decrease (increase); when speculators sell futures, it is easy for them to become emotionally attached to them. However, some speculators do not rely on estimates of supply and demand, but utilize price charting techniques or other devices that react to changes in price. Then the money drains (floods) from the market by selling (buying) contracts, and futures prices are decreased (increased) beyond that which is necessary to counterbalance the actual magnitude of increased supply of hogs.

The overly pessimistic reaction results in lower live hog futures prices than warranted by market conditions. As a result spot prices often exceed futures price, and an inverted market is said to have occurred. In fact, the normal condition for a nonstorable commodity has historically been cash over futures. As a result, a long strategy can enhance speculator profits.

Hammonds (1972) considers that cash market delivery is generally more convenient and more reliable than futures market delivery; the cash market may command a slight premium. Cognitive factors seem more likely to have played a role in generating the obtained results. This overreaction of futures price is consistent with the so-called "overreaction hypothesis," that is, an individual tends to overweight recent information and underweight prior data in revising his belief.

The results indicate that the forecasts are too low when making low price forecasts and too high when making high price forecasts. Irwin, et al. (1992) interprets this behavior that forecasters appear to be overly pessimistic when predicting at low price and overly optimistic when predicting at high prices.

For example, in Figure 5.3, the overreaction diagram, when a forecaster predicts a price of $40 per hundredweight, the actual price will ultimately be $45 per hundredweight. That means that the forecaster underestimated the actual price $5 per hundredweight. Furthermore, when a forecaster predicts $60 per hundredweight, the actual price turns out to be $55 per hundredweight. In this case, this forecaster overestimated the actual price $5 per hundredweight.

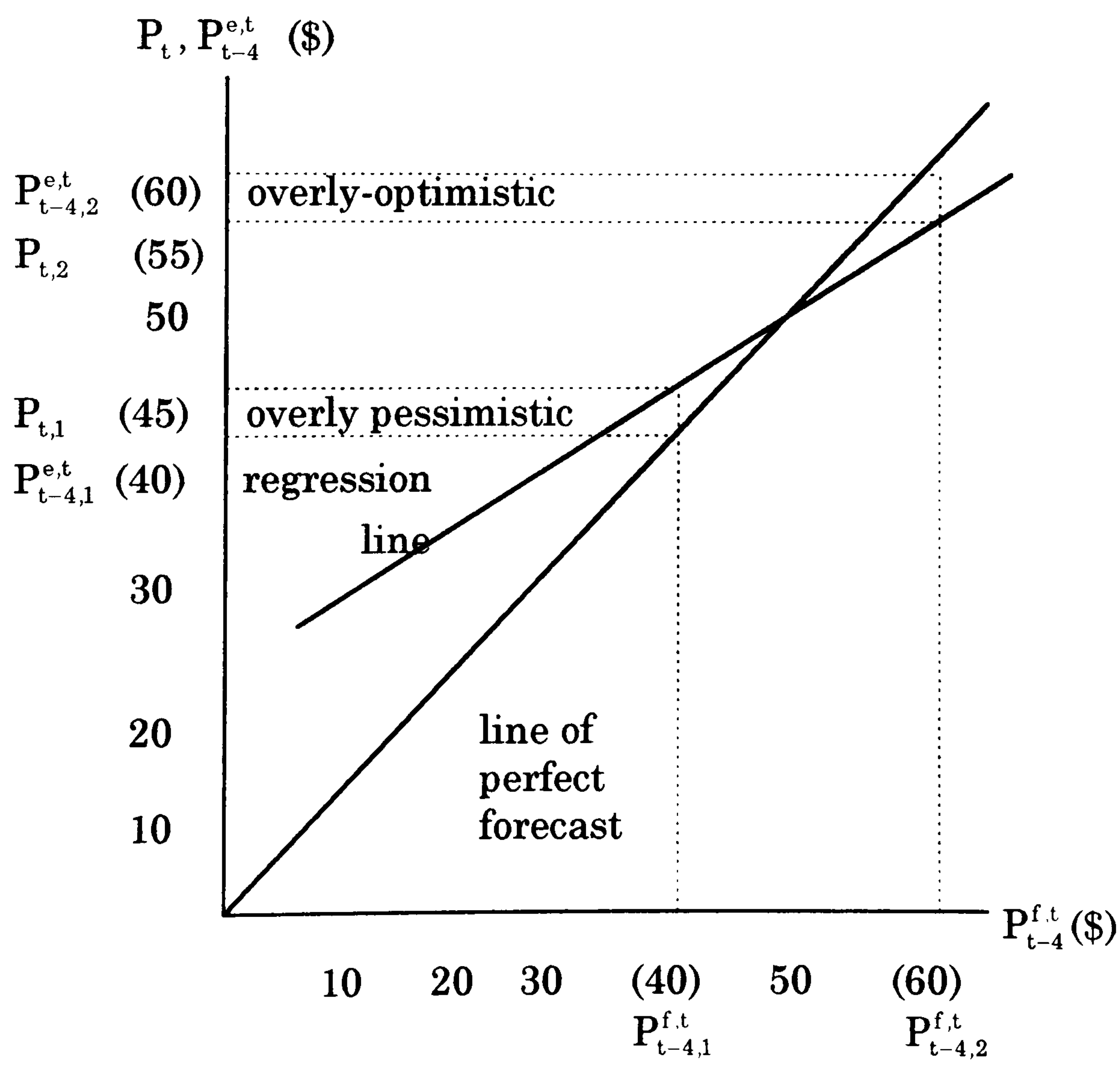


Figure 5.3 Overreaction Diagram

5.3.4 Cointegration Test of Pricing Efficiency

Regressing the level of actual hog price (P_T) on the futures price ($P_t^{f,T}$) from 1986, Qtr II to 1990, Qtr II, obtained in the cointegration regression

$$P_t = 33.96 + .33P^{f,t}_{t-4}, \tag{5.35}$$

$$DW = .76.$$

Since DW = .76 from the regression, where sample size = .17, is less than the lower limit [R_l] for α =.05 given by Sargan and Bhargava (1983). Thus, u, an error term, is not stationary. Therefore, the value of DW =.76 does not allow rejection of the null of noncointegratability. Consequently, P_t and $P^{f,t}_{t-4}$ are nonintegrated. Therefore, there is pricing inefficiency in the hog futures. P_t and $P^{f,t}_{t-4}$ tend to divide without bound. As a result, $P^{f,t}_{t-4}$ has little predictive power over the movement of P_t.

This result is consistent with Leuthold (1979). He found the evidence for cointegration for nearby contracts, but perhaps, not for more distant contracts.

This result is also consistent with Schroeder and Goodwin (1991). They state that "thus, as expected, the farther from contract expiration, the more the cash and futures prices tend to diverge from each other"(p. 693). This is clearly inconsistent with the market efficiency hypothesis.

5.3.5 Weak Information Efficiency

Test results using the direction of change show that unbiasedness is rejected for the predicted price of futures prices. Hence, rationality is rejected for the futures price. As a result, it is unnecessary to test for efficiency for predicted price of futures price. The forecast price from Models I and II are unbiased. Further tests are necessary to determine whether the three unbiasedness series from Models I and II are efficient. Efficiency implies that forecast errors are uncorrelated.

Model I:

$$\begin{gathered} P_t - P^{e,t}_{t-4} = 23.42 + .33\, P_{t-1} - .24\, P_{t-2} - .11\, P_{t-3} - 66\, P_{t-4}. \\ F = 1.302; RMSE = 7.81 \quad DW = 1.97 \end{gathered} \tag{5.36}$$

Model II:

$$\begin{gathered} P_t - P^{e,t}_{t-4} = 9.61 + .32\, P_{t-1} - .06\, P_{t-2} - .04\, P_{t-3} - 40\, P_{t-4}. \\ F = .77; RMSE = 7.28 \quad DW = 2.04 \end{gathered} \tag{5.37}$$

The critical F value for 5% level of significance $F_{.05}$ (4,12) is 3.26. Comparing the F computed with each level of significance, implies that this information P_{t-1},, P_{t-2}, P_{t-3}, and P_{t-4} has been used efficiently in forming the forecast. In other words, the forecast error is uncorrelated with past values of the predicted variables. It then becomes obvious that the forecast error depends on purely random error terms. The test results indicate that the efficiency criterion is satisfied for forecast prices from Models I and II. The DW statistic exhibits the non-presence of serial correlation (Durbin Watson Statistic: 5% significance points of d_L and d_u = .78 and 1.9). Bonham and Dacy (1991) call this property a weak orthogonality test. Past prices are not correlated with forecast error; therefore, they cannot be used to improve the forecast.

5.3.6 Sufficient Orthogonality

Model I:

$$P_t - P^{e,t}_{t-4} = -470.95 + .13\, P^{f,t}_{t-4} - .012\, COT$$

$$-3.29\, Pro + 2.12\, Pop - .0004\, SF \qquad (5.38)$$

$$F = 2.38;\ RMSE = 6.77 \quad DW = 1.86$$

Model II:

$$P_t - P^{e,t}_{t-4} = -383.23 + .02\, P^{f,t}_{t-4} - .01\, COT$$

$$-2.67\, Pro + 1.78\, Pop - .003\, SF \qquad (5.39)$$

$$F = 2.02;\ RMSE = 6.17 \quad DW = 2.18$$

The critical F value for 5% level of significance $F_{.05}$ (5,11) is 3.20.

By comparing F computed and F critical values from each equation, the result shows that the forecast error is not correlated with the information set available at the time of prediction. Thus, Models I and II do not reject the sufficient rationality of hog prices. Also the DW statistic exhibits the non-presence of serial correlation (Durbin Watson Statistic: 5% significance points of d_L and d_u = .66 and 2.10).

The pricing inefficiency in hog futures markets can be explained as the result of the overreaction of participants. The test of the null hypothesis for unbiasedness, weak form information, and sufficient rationality does not reject the forecast prices from Models I and II. Therefore, the forecast prices are unbiased and efficient, and as a result, are rational. This study concludes that the criteria of Rational Expectations in Models I and II are met.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Summary

Many economists have summarized the intuitively plausible argument that futures prices provide information that can be used to guide production in hog operations. However, it is inefficient for the futures market to act as a guide for hog production compared to field crops, because the time required for hog production is longer than that of field crops. The longer time required means the less accurate the futures contract becomes; and therefore, forecasts based on futures prices are ineffective for predicting the subsequent spot price of hogs.

A substantial body of research concerning the pricing efficiency in the live hog futures markets reveals many controversial results due to the different methodologies and time periods studied. One group of researchers found that the hog futures market produces inefficient pricing, while another group indicated that this market has efficient pricing. However, Martin and Garcia (1981) considered the time horizons from one to eight months prior to maturity. They found that futures prices were unbiased estimates of subsequent spot prices. The results of this dissertation correspond with those of Leuthold and Hartman (1979, 1981) in that the hog futures markets have not performed efficiently. This study indicates that a simple econometric model using only public information was more accurate in forecasting than was the live hog futures market. When price expectations are formed, the farrow-to-finish producer should consider using at least four quarters with either the econometric model or the futures prices to estimate the subsequent spot price. The forecast horizon of eight months, used by Martin and Garcia should be appropriate for the finisher who buys feeder pigs.

However, no research has analyzed the role of futures price as a predictor of the subsequent spot price for more than eight months. This study extends this work. In the case of the farrow-to-finish hog enterprises, producers should employ futures price information at least twelve months or four quarters ahead for effective production planning.

This dissertation focused on testing whether the futures price is efficient by studying the relationship among the futures price, the subsequent spot price, and the forecast price (out-of-sample forecast). The role of expectations in the producer's decision making must be considered.

The regressions of a live hog market model can be summarized into five equations:

Equation 1, demand function

Equation 2, desired pig crop

Equation 3, pig crop adjustment

Equation 4, supply function

Equation 5, market clearing condition

Researchers are becoming increasingly interested in the study of expectations and expectations formation. Expectations about future price play an important role in decision making of pig crop production. A fundamental model was developed, then modified into two models, depending on the producer's expectations in the desired pig-crop equation.

The desired pig-crop equation of Model I uses price expectations formed at time $t-4$ $\{E_{t-4}(P_t | I_{t-4})\}$,which are derived from a reduced form of that structural model. This model is called the Rational Expectations Model.

Model II uses the change of price expectations at time t-4 and time t-5, that is $E_{t-4}(P_t | I_{t-4}) - E_{t-5}(P_t - 1 | It-5)$. $E_{t-5}(P_{t-1} | I_{t-5})$ is derived from lagging $E_{t-4}(P_t | I_{t-4})$ by one period. In addition, Model II includes price risk of hogs and corn in the model. In this study, Model II indicates Rational Expectations with price risks.

Steps of estimation $P_{t-4}^{e,t}$ of Model I and II:

The producers can have the estimated price expectation $E_{t-4}(P_t | I_{t-4})$ by running a regression on the reduced form from equation (4.21) in which every variable is substituted by the actual value.

The estimated pig crop Pig_{t-2} can be derived by substuting an estimated $E_{t-4}(P_t | I_{t-4})$ into the pig crop equation (4.22) and then running a regression. In order to get an estimate of hog quantity supplied Q_t^s into the demand equation (4.24), then run a regression. Therefore, an estimated $P_{t-4}^{e,t}$ can be obtained. Steps of estimation $P_{t-4}^{e,t}$ of Model II are the same as Model, but the process musts work through equation (4.45), (4.46), and (4.49) respectively.

To estimate the model, this study used ordinary least squares and recursive method instead of Full Information Systems (FIS) for three reasons. First, a long interval of many months elapsed between the time of decision making and marketing. As quoted by Bigman, the simultaneous method of estimation should not be used. Second, this study chose to avoid the specification bias instead of the simultaneity bias. Third, FIML method created an unexpected sign in the demand equation.

Model I has a negative relationship between the pig-crop and price expectations. If the hog cycle existed, then the cobweb phenomenon existed. The actual prices should fall on the demand curve. Rational persons will capture the negative relationship between price and quantity demanded by producing along the demand curve.

Model II used the change in price expectations (conversely, Model I uses the level of price expectations). Therefore, Model II assumes that producers perceived the price risks of hogs and corn over a long period of time. Thus, in order to increase production, the expected price at time t must increase as compared to the expected price at time t-1. Inherently, $E_{t-4}(P_t | I_{t-4})$ is greater than $E_{t-5}(P_{t-1} | I_{t-5})$. As a result, the producer is looking for the expected price trend. A positive relationship exists between the level of the desired pig-crop and the change in expected price of hogs. Also, the coefficients of the other estimates of Models I and II exhibit the expected signs. Then two modified models, Models I and II, are produced and can be used to forecast the subsequent spot prices.

Models I and II do not reject the unbiasedness test at the .05 significance level. Additionally, the forecast prices for hogs in Models I and II do not reject the Weak Information Efficiency and Sufficient Orthogonality test. The resulting forecast from Models I and II yield a good forecast because the models utilize all available information during the forecasting process. Utilizing all available information means that when the forecast must be formulated for the next quarter, the results for the most recent quarter are included to generate the most accurate forecast price possible. For example, this forecasting process uses the first through the forty-second observations to forecast the forty-sixth observation; then the first through the forty-third observations will be used to forecast the forty-seventh observation, and so on.

Rational Expectations Models I and II use the knowledge of economic structure to enhance the efficiency of predictions or forecasts. It is the prediction from economic theory using all the relevant information available at the time the forecast is made and is referred to as rational expectations in variables. The idea of rational expectations may well have a rational place in models, though not in the clear cut forms which have been proposed.

Between the two models, Model II yields better predictions of the subsequent spot price. Even though Models I and II perform the price discovery function better than the futures price, Models I and II have a higher RMSE than the futures market. A possible explanation for the comparatively high RMSE is that the RMSE will tend to be lower for forecasts containing many similarly sized errors relative to forecasts that contain, on average, smaller errors, as well as several very large errors. An estimator is unbiased if the average value of the forecast equals the value of the variable to be forecast. Therefore, forecast prices might provide an unbiased forecast even though containing very large errors (RMSE).

Instead of relying solely on standard statistical technique as suggested in the literature on future price behavior, this study used a trading strategy (based on forecasts from Models I and II) to determine if profitable arbitrage opportunities exist. Models I and II produced excess profit per contract, e.g., $1,270.00, and $1,207.35, respectively. Evidence of profitable arbitrage opportunities suggests that the futures market is inefficient.

Since both subsequent spot price and futures price are unit roots; therefore, the cointegration test is another method to test the pricing efficiency. The cointegration test was used to confirm that the futures price is an inadequate predictor of the subsequent spot price.

The results from the empirical study of unbiasedness tests, trading strategies, and cointegration tests indicate that there is pricing inefficiency in the hog futures market.

The results from the empirical study, unbiasedness tests, suggests that the forecasting performance of the econometric models are superior to live hog futures prices since the live hog futures prices are biased predictions of the subsequent spot price at a .05 level of significance.

Not only are the forecast prices for Models I and II are unbiased estimates of subsequent spot prices, but they also satisfy the criteria of weak information efficiency and sufficient orthogonality. Therefore, $P_{t-4}^{e,t}$ from Model I and II are considered to be rational expectations price.

One possible explanation for the pricing inefficiency in the hog futures market came from the overreactions of the participants. The research results show pricing inefficiencies in the hog futures market. Therefore, the futures price cannot produce reliable signals to guide efficient allocation of resources. The resulting oversupply and undersupply in the economy causes price uncertainty. Eventually, the misallocation of resources becomes embedded in the U.S. hog industry because P_t is not equal to $P^{f,t}_{t-4}$. However, by using the risk minimizing hedging, the producers can avoid the drop in cash price. Therefore, they can reduce the risk (variance) of income fluctuation or reduce the uncertainty attached to price movements.

Thus, the price discovery function cannot rely solely on the live hog futures market. Theoretically, futures market prices should be an unbiased estimator of subsequent spot prices. Therefore, the futures price should be used as an alternative predictor along with the forecast price from the econometric model because the available evidence suggests the existence of futures markets improve the quality of the information flow about the products. The combined prediction may improve forecasting performance and, consequently, resource allocation.

6.2 Suggestions

There are four constraints to this study. First, the number of observations was limited. In studies from 1975, Qtr I, to 1990, Qtr II, the econometric model did not have a sufficient time period to maintain the statistical richness of data. In order for the solution to converge, a study must use data of at least 40 observations to have sufficient data to conduct an out-of-sample test.

In addition, there were limitations of methods used to forecast exogenous variables. This problem emerged as a result of limited observations. A study should have at least 50 observations to use ARIMA effectively. Therefore, the exogenous variable cannot be predicted exactly. In addition, Salmon and Wallis (1984) suggest that the error in these projections contributes to the overall out-of-sample forecast errors.

Secondly, in the case of testing the unbiasedness, this study does not take the problem of overlapping observations completely into consideration. This problem introduces a high order moving average process into the data. The property of the data will affect the estimated coefficients' standard errors. The Hansen-Hodrick (1980) estimation procedure can be used to correct the model's error term for serial correlation. This study does not use the Moving Average (MA) process because the loss of information will be very severe for a small number of observations. SAS Procedure Autoregression can be used to calculate the estimate of the parameters in a model having an autoregressive error structure. Then, the statistical problem of overlapping observation may be avoided.

Third, Pesaran (1984) describes theoretically that economic agents cannot have correct expectations (even on the average) because their environment is fundamentally unstable. However, this study overcame this problem by revising the model for each forecast four periods ahead. The serially correlated errors obtained from data in the historical period are important factors in improving the forecasting performance. Model revision is a continuous process. But, it is hardly likely that such changes will suddenly improve the forecasting effectiveness of the models.

Fourth, in the future, these Models I and II will be useful because of the fact that as the size of the sample increases, the sample variance decreases. To recognize the importance of the sample size, researchers should not react to large and small samples in the same way. This model can be used effectively without the sample bias. The test statistics in the Efficient Market Hypothesis are only asymptotically valid; since their small sample properties are not well known, care must be taken in the interpretation.

Should it be possible for at least the model consistently to outperform the futures market? In this case, the forecast price can be used as a reliable forecast for the subsequent spot prices, to formulate the optimal plans of production. In reality, it is convenient for hog producers to form their expectations of live hog prices based on the futures price. In addition, futures prices per se are informationally efficient, because the public information used is gratis.

Futures prices, however, can be used by producers to help insulate themselves from changing relationships between input and output prices during the production process. Since the information is free, producers may be well advised to investigate the futures market to determine its use in their overall marketing plan. Hog producers, who can adjust their operations to vary their output and lock-in a profitable price level of production, could possibly increase their average returns.

Suppose it appears that some people do earn an above-average profit from speculations. Does this mean that the live hog futures market is inefficient? The answer is, not necessarily. There may be other reasons why large profits accrue to speculation. In particular, it may be the case that speculators require a premium to compensate them for the risk in a hog futures position that they may lose rather than make money. The finding of above-normal profits from speculation may simply reflect the fact that the market, in effect, "pays" such a risk premium.

Dusak (1973) found that average returns on wheat, corn, and soybeans over the period from 1952 to 1967 were close to zero. Bodie and Rosansky (1980) used the simple strategy of buying futures contracts and holding them for three months. They found the returns close to the returns from the U.S. stock market (Standard and Poor's 500). When using three commodities and a shorter time period examined by Dusak, the returns were close to zero.

The research results tend to suggest that speculators do not earn a risk premium. Therefore, the futures market is unlike an insurance scheme in which speculators earn a risk premium. The question remains: Are the returns, by buying and holding strategies, concentrated in a small number of commodities especially non-storable commodities?

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APPENDIX

HOG MODELS

A.1 Leuthold and Hartman (1979)

Leuthold and Hartman (1979) developed a recursive two-equation demand and supply model using monthly data as a performance norm. The underlying assumptions of the model closely follow that of the cobweb model. The L-H model was designed to forecast hog slaughter and cash-hog price. The rudiments of this model can be summarized in two equations. The supply equation explains the hog slaughter monthly in relation to the sow farrowing six months previously, hog-corn price ratio lagged 24 months, 11-month dummy variables to shift intercept, and 3-slope dummy variables for sow-farrowing for September, October, and November. The demand equation relates average price of barrows per hundred weight to hog slaughter (in supply equation), personal income, and 11-month dummy variable. The model is stated as follows.

Supply Equation:

$$Q^S = f(SFW_{t-6}, HCR_{t-24}, D_i, D_j)$$

Demand Equation:

$$P_t = g(Q_t^s, PI_t, D_i),$$

where

Q_t^s = hog slaughter monthly, US, 1,000 head;

SFW_{t-6} = 1,000 head, ten states, six months previously;

HCR_{t-24} = hog- corn price lagged 24 months"

P_t = average price of barrows and gilts, eight markets, dollars per hundred weight (reflecting seven markets beginning in 1970 due to the decline in the Chicago market;

PI = personal income, U.S., in billion dollars;

Di = 11 - month dummy variable to shift intercept, February through December;

Dj = 3 - slope dummy variables for sow farrowing for September, October, and November.

SFW_{t-6} = 1,000 head, ten states, six months previously;

HCR_{t-24} = hog-corn price lagged 24 months;

P_t = average price of barrows and gilts, eight markets, dollars per hundred weight (reflecting seven markets beginning in 1970 due to the decline in the Chicago market).

Since the hog-corn price ratio is lagged 24 months, once the amount of sows farrowing are known, values of the independent variables can be inserted into the supply equation to generate a predicted price.

A.2 Leuthold and Hartman (1981)

The model is a three-equation recursive model to forecast hog prices. Equation 1 can be seen as determining output for pork production. The supply for pork is equal to the number of hogs slaughtered (head) x average hog slaughter weight (pounds) x pig saved litter. Equation 2 is the demand equation for pork. It relates the wholesale price of pork to consumer price index at time t (1964 = 100), consumer price index with time trend and dummy variable, pork production (from supply equation), cold storage stacks of pork, and seasonal dummy variable. Equation 3 is the demand for hogs equation. It relates the price of barrows and gilts to the wholesale price of pork previously, pork production, and seasonal dummy variable. Leuthold and Hartman (1981) still used a recursive model, but this time they used a three-equation model instead of a two-equation model as in 1979.

Supply equation:

$$PP_t = Q^s_t * AHSW_t * PS_t$$

Demand for pork:

$$WPP_t = f(CPI_t, CPI*\alpha T, PP_t, CO_{t-1}, D_2, D_3, D_4)$$

Demand for hogs:

$$P_t = g(WPP_{t-1}, PP_t, D_2, D_3, D_4),$$

where

PP_t = pork production, million pounds;

Q^s_t = hog slaughter, million head;

$AHSW_t$ = average hog slaughter weight, pounds;

PS_t = pigs saved per litter;

WPP_t = wholesale price of pork, pork loins, 8-14 pounds;

CPI_t = consumer price index (1964 = 100);

α = (0,1) dummy variable, 1 for t-2 and t-1, 0 otherwise;

T = time trend;

CD_{t-1} = cold storage stocks of pork, beginning of the quarter, million pounds;

D_i = seasonal dummy variables for quarter i, where

i = 2, 3, 4; and

P_t = price of barrows and gilts, 8 or 7 markets, dollars per

hundred weight.

A.3 Dixon and Martin (1982)

There is one equation in Dixon and Martin (1982). By performing a Koyck transformation, the quantity supplied of pork depends on the seasonal dummy variables, five-quarter lags on hog prices and five-quarter lags on feed prices, and the decay of the quantity supplied. The parameters then were estimated by OLS.

Pork supply model:

$$Q^s_t = f\{D_1,D_2,D_3,(P_{t-5}+\lambda P_{t-6}+\ldots),(P^f_{t-5}+\beta P^f_{t-6}+\ldots)\}$$

Performing a Koyck transformation gives:

$$Q_t = g(D_1,D_2,D_3,\ P_{t-5},\ P^f_{-5},\lambda Q_t)\},$$

where

D_{it} = binary variables as quarterly intercept shifters;

P_{t-5} = five-quarter geometric lags on hog prices;

P^f_t = feed prices. Feed price is a linear combination of 88% of the price No. 2 corn at Chicago and 12% protein soybean and meal;

β = rate of decay is the same for both hog and feed prices; and

Q^s_t = the quantity supplied. Supply is in hundreds of millions of pounds of carcass weight and prices are in dollars per pound.

The parameters were estimated by OLS.

A.4 Brandt and Bessler (1983)

The forecast price of all barrows and gilts at seven U.S. terminal markets depends on the logarithm of total disposable income previously, number of sows farrowing at quarter t-2, number of sows farrowing at quarter t-3, hog-corn price ratio at quarter t-1, pounds of meat from U.S. commercial cattle slaughter at quarter t-1, and number of broiler-type chicks hatched.

The econometric estimation is a single equation in reduced form of a structural model:

$$\hat{P}_{t+1} = f(\ln DPI_t, SFW_{t-1}, SFW_{t-2}, HCR_t, Q_{B,t}, HTC_{t-1}),$$

where

$\hat{P}$ = the forecast price of all barrows and gilts at seven U.S. terminal markets;

$lnDPI_t$ = logarithm of total disposable income;

SWF = number of sows farrowing in 14 states, quarterly;

HCR = hog-corn price ratio for Omaha;

$Q_{B,t}$ = pounds of meat from U.S. commercial cattle slaughter; and

HTC = number of broiler-type chicks hatched.

A.5 Marsh (1984)

The essentials of this model can be separated into two equations: one as barrow and gilt slaughter and another as sow slaughter. For the barrow and gilt slaughter equation, the commercial slaughter of barrows and gilts depends on pig crop at time t-2, pig crop at time t-3, price of barrows and gilts, and seasonal dummy variables. For the sow slaughter equation, the sow slaughter depends on sow slaughter at time t-1, sow slaughter at time t-2, and seasonal dummy variables.

(1) Barrow and gilt slaughter:

$$Q^s_t = f(D_2, D_3, D_4, Pig_{t-2}, Pig_{t-3}, P_t),$$

where

Q^s_t = commercial slaughter of barrows and gilts, 1,000 head;

D_i = seasonal binary variables, j=2,3,4;

Pig_t = pig crop, 1,000 head;

P_t = price of barrows and gilts, U.S. No. 1-2, 220-240 pounds, 7 markets combined.

(2) Sow slaughter:

$SWS_t = f\{D_{74\text{-}3}, D_{75\text{-}1}, D_2, D_3, D_4, HCR_t,$

$E(SWS_{t-1}), E(SWS_{t-2})\}$,

where

SWS = number of sows slaughtered;

$D_{74\text{-}3}$ = the third quarter of 1974;

$D_{75\text{-}1}$ = the first quarter of 1975;

HCR = hog-corn price ratio; and

E = expectation operator.

A.6 Holt and Johnson (1983)

The essentials of this model can be summarized in seven equations. Equation 1 is the breeding herd inventory equation. It relates the breeding herd inventory to the price of barrows and gilts up to eight periods previously, the price of feed up to eight periods previously, the interest rates up to eight periods previously, the breeding herd lagged four quarters, and the seasonal dummy variables.

Equation 2 is the sow slaughter equation. Sow slaughter depends on the breeding herd inventory at the beginning of the period and the three economic variables (hog price, interest rate, and feed price) that reflect changing expectations about the profitability of hog production.

Equation 3 is the pig crop equation. The pig crop depends on the level of the breeding herd, the information pertaining to the structural shift, and the seasonal variables.

Equation 4 is the barrow and gilt slaughter equation. The barrow and gilt slaughter depends on the pig crop one quarter previously, the pig crop three quarters previously, and the dummy variable.

Equation 5 is the live weight of sows. The live weight of sows is specified as a function of lagged output prices and seasonal intercept shifters.

Equation 6 is the live weight of barrows and gilts. The barrow and gilt slaughter weight responds to the current price and the price of barrows and gilts at time t, price lagged one quarter, and dummy variable.

Equation 7 is the domestic pork production. This identity says that the domestic pork production is equal to the product of barrow and gilt slaughter and live weight of barrows and gilts plus sow slaughter multiplied by the live weight of sows.

(1) Breeding herd inventory (BHI):

$$BHI = f(P_{t-1}, P^f_{t-1}, IR_{t-1}, BHI_{t-4}, D_i),$$

where

P_{t-1} = the seven-market price of barrows and gilts lagged one quarter;

P^f_{t-1} = the price of feed lagged one quarter;

IR_{t-1} = the interest rate lagged one quarter;

BHI = the breeding herd; and

D_i = 2, 3, 4.

(2) Sow slaughter (SWS):

$$SWS = g(BHI_{t-1}, P^*_t, P^{f*}_t, IR^*_t, D_i),$$

where

BHI_{t-1} = breeding herd inventory at the beginning of the period;

$$P^*_t = \sum_{i=1}^{3} \alpha_i P_{t-i};$$

$$P^{f*}_t = \sum_{j=0}^{2} \alpha j P^f_{t-j}; \text{ and}$$

$$IR^*_t = \sum_{k=1}^{3} \alpha k \, IR_{t-k}.$$

(3) Pig crop (Pig_t):

$$Pig_t = h(BHI_t, BHI_t{*}D_2, BHI{*}T, BHI{*}T{*}D_2, D_i),$$

where

T = a linear time trend (1967.00 = 0.25) and

D_2 = an intercept shifter for quarter two.

(4) Barrow and gilt slaughter (Q^s_t):

$$Q^s_t = I(Pig_{t-1}, Pig_{t-2}, Pig_{t-3}, D_2, D_3, D_4).$$

(5) Live weight of sows (LWSS):

$$LWSS = m(P^f_{t-1}, P^f_{t-2}, D_2, D_3, D_4).$$

(6) Live weight barrows and gilts (LWQ^s_t):

$$LWQ^s_t = f(P_t, P_{t-1}, D_1, D_2, D_3).$$

(7) Domestic pork production (DPP):

$$DPP = LWQ^s_t * Q^s_t + LWSS * SWS.$$

Holt and Johnson assumed that (1) all expected prices are functions of current and lagged farm prices and (2) cost of production studies (USDA) continue to show that feed is the most important variable expense in hog production. They found that current prices have no influence on the level of the reproductive herd and so were excluded from the final estimation. One of the CJAE (Canadian Journal of Agricultural Economics) referees suggests that Holt and Johnson's model should have the feedback through market price if a demand block were included.

A.7 MacAulay (1978)

This is a spatial equilibrium model that can be summarized in three equations. (Although there are many regions, this study chose only one region in order to see the model specification.)

Equation 1, the consumption demand equation, explains number of pounds per capita pork disappearance in relation to the seasonal dummy variable, the hog price, the beef price, and per capita disposable income. (A logarithmic transformation of the income variable was used to provide a closer approximation of an Engel curve.)

Equation 2, the stock demand equation, relates the stock demand to the seasonal dummy variable, dummy variable for change in pattern of holding stocks, the price of hogs, pork supply, and stock demand at previous quarter.

Equation 3, the supply equation, relates output of pork supply to the seasonal dummy variables, the hog price with a five quarter lag, the feed price, the farm grain stocks, the beef cattle margin as an opportunity-cost variable lagged five quarters, and pork supply in the previous quarter.

The Identities equation included in the system relates demand to the trade flow and closing stocks and supply to the trade flow and opening stocks.

Consumption demand:

$$Q^D_t = f(S_1, S_2, S_3, P_t, PBF_t, \log PI_t).$$

Stock demand:

$$I_t = g\{S_1, S_2, S_3, STKDUM_t, (P_t - P_{t-1}),$$
$$PHOG1t, QS1_t, STK1_{t-1}\}.$$

Supply:

$QS1t = h\{SS1, SS2, SS3, PHOG1_{t-5}, PFEED1_{t-1}, GRNSTK_t,$

$(11.0PS1 - 45PFCV1)_{t-5}, QS1_{t-1}\},$

where

Q_t = per capita pork disappearance (lb/head);

P_t = hog price ($/CWT), t-5 is five-quarter lag;

I_t = closing stock demand (mil. lb);

Q_t = pork supply;

S_i = seasonal dummy variable;

PBF_t = beef price ($/CWT) proxied by PS_i;

PS_i = price of A1, A2, C (choice) steers;

IDUM = dummy variable for change in pattern of holding stocks;

PI_t = per capita disposable income ($/hd/Q);

PC_t = barley or corn prices (barley, $/CWT; corn, $/bu);

$PFCV_i$ = feeder calf price ($/CWT); and

$GRNSTK_t$ = stocks on prairie farms (mil. tons).

A number of studies exist on supply response in the hog section. Most studies of hog supply response deal with the time lag between a change in the variable determining supply and the change in production level. This lag is attributable to a biological lag in production factors and a lag in decision making. It is assumed that the full supply response to price and other variable changes takes longer than one quarter. To capture this effect, a set of geometrically declining weights were imposed on each variable in the supply response functions.

The variables in the supply equations are seasonal dummy variables (S_1, S_2, and S_3); the hog price (P_t) with a five-quarter lag. The feed price (PC_t) is the major variable cost component; feed availability in western grains is measured in terms of prairie farm grain stocks (GRNSTK); and the beef cattle margin, as in opportunity-cost variable, lagged five quarters (11.0PS-4.5PFCV). Zwart (1973) found that a five-quarter lag was appropriate. Implicit is an assumption that the effect of the above variables with lags of less than five periods is negligible.

The demand equations for consumption and closing stocks were estimated using two-stage least squares (2SLS) and the supply equation using ordinary least squares (OLS) for the period from the third quarter of 1966 to the fourth quarter of 1976. The 2SLS method was used to estimate the consumption and stock equations because of the simultaneous determination of consumption and stock demands. Once the system is fully operational, improved estimation methods can be incorporated to account for some of the more subtle problems encountered in the particular formulation. At this point, however, 2SLS and OLS are satisfactory.

A.8 Heien (1975)

Heien (1975) began his approach by specifying that the total number of pigs slaughtered depends on the expectation of farm price of pigs and feed cost ratio. Then he substituted the expected price ratio by the distributed lag of the farm price of pigs and feed cost.

The total production of pork depends on the total number of pigs slaughtered, labor input, technological change, and capacity measure of the pork industry. Thus, the supply curve of pork can be derived from the maximized behavior. The resulting supply curve is in the farm. Total pork production depends on the ratio of the retail price of pork and the farm price of pigs, the ratio of the retail price of pork and the wage rate, the capacity measure for the pork industry, and the technological change.

The demand side is from the maximizing producer utility function. The retail price of pork depends on total supply of pork per capita, total supply of fed beef per capita, total supply of nonfed beef per capita, retail price of chicken, retail price index of all other nondurables and services (except beef, pork, and chicken), and price of fish.

$$TNPS = f\{(FPP/FCP)^{e}\} = f\{(FPP/FCP)^{-1}\}$$

$$TNPS = f\{(FPP/FCP)_{-1}, (FPP/FCP)_{-2}, (FPP/FCP)_{-3}\},$$

where

TNPS = total number of pigs slaughtered;

FPP = the farm price of pigs;

FCP = the feed cost; and

FPP/FCP = a proxy for the expected price ratio.

A.9 Roy and Roberson (1989)

This is a market model which can be summarized in four equations. Equation 1 is the retail price consumption equation. The retail price of pork depends on the consumption of pork, disposable personal income, the consumption of beef, and the consumption of poultry.

Equation 2 is the retail price-live hog price equation. The live hog price depends on the retail price of pork, the weekly goods earnings of production workers, time variable, and the commercial production of pork.

Equation 3 is the storage stocks of pork products equation. The storage stock of pork at time t+1 (one period ahead) depends on the difference between the expected consumption of pork at time t+1 [$E(C_{t+1})$] and the expected production of pork at time t+1 [$E(Q_{t+1})$]. The observable equation of $E(C_{t+1}) - E(Q_{t-1})$ is $[R_t, I_{t+1}, S_t, (F_{t-1} * L_{t-1})]$.

Equation 4 is simply the market clearing identity that says that the consumption of pork at time t is equal to the production of pork plus the change in the stock of pork. This is a system simultaneous equation. Given the information from outside, the equation can be solved for the endogenous variables: demand, supply, price, and inventories.

Roy and Roberson (1989) consider (1) the short-run supply for market hogs is inelastic for any present market period because pigs farrowed take approximately two quarters to grow into market hogs. Therefore, at the time of marketing, producers have a relatively fixed supply of market animal; (2) the inelastic consumer demand translates into an inelastic live hog demand; (3) the live hog market seems to follow the cobweb phenomenon; and (4) they put expectations into the model.

The structural relations for the quarterly retail pork and live hog prices are presented as follows:

Retail price-consumption equation:

$$P^r_t = f_1(C_{pk,t}, DPI_t, Q_{b,t}, Q_{p,t}).$$

Retail price-live hog price equation:

$$P_t = f_2(P^r_t, WPC_t, T, Q_{pk,t}).$$

Storage stocks of pork products equation:

$$S_{t+1} = f_3[E(C_{pk,t+i}) - E(Q_{pk,t+i})].$$

The observable equation:

$$S_{t+1} = f_4[R_t, DPI_{t+1}, S_t, (F_{t-i} * L_{t-i})].$$

The market clearing identity:

$C_{pk,t} = Q_{pk,t} + S_t - S_{t-1},$

where

$E(DPI_{t+1}) = DPI_t + DDPI_t = DPI_t + (DPI_t - DPI_{t-1});$

$E(Q_{pk,t}) = f_1(F_{t-2}{*}L_{t-2});$

$E(Q_{pk,t+1}) = f_2(F_{t-1}{*}L_{t-1});$

E_t = expectation operator;

C_t = the civilian consumption of pork in the U.S. during the quarter, million pounds;

$P^r{}_t$ = the weighted average retail price of pork products during the quarter, adjusted to live animal equivalents, cents per pound, by the reciprocal of live animal equivalent factor;

DPI_t = the disposable personal income for the quarter at the seasonally adjusted annual rate, billion dollars;

$Q_{B,t}$ = the consumption of beef during the quarter, million pounds;

$Q_{P,t}$ = the consumption of poultry during the quarter, million pounds;

P_t = the seven market weighted average of live hog prices, dollars per hundred weight;

WPC_t = the average weekly gross earnings of production workers in the meat packing plants during the quarter;

T = a time variable;

$Q_{pk,t}$ = the commercial production of pork during the quarter, million pounds;

S_t = the stocks of pork at the beginning of the quarter, million pounds;

F_t = the number of sows farrowed during the quarter, million head;

L_t = the estimated average number of pigs saved per litter during the quarter; and

DPI_{t+1} = the expected income in the next quarter.

A.10 Shonkwiler and Spreen (1982)

By studying the relationship between hog slaughtering and a hog-corn price ratio series, Shonkwiler and Spreen (1982) used transfer function or dynamic regression techniques which permits the tests of causal relationships and a systematic means for specifying distributed lag forms.

$$\begin{vmatrix} \Phi_{11}L & \Phi_{12}L \\ \Phi_{21}L & \Phi_{22}L \end{vmatrix} \begin{vmatrix} HCR_t \\ Q_t \end{vmatrix} = \begin{vmatrix} \theta_{11}(L) & \theta_{12}(L) \\ \theta_{21}(L) & \theta_{22}(L) \end{vmatrix} \begin{vmatrix} e_{xt} \\ e_{yt} \end{vmatrix}$$

where

$\phi_{ij}(L)$ and $\theta_{22}(L)$ = finite polynomials in lag operator L;

HCR_t = a linear combination of the hog-corn price ratio X_t; and

Q_t = hog slaughter.

A.11 Bessler (1984)

A vector autoregression was estimated on this five variable system: U.S. hog prices, sow farrowing, hog slaughter, corn prices, and disposable income. By applying ordinary least squares regression to each equation, each variable is thus regressed on lagged values of itself and on lagged values of each of the remaining variables. In addition, a constant and a time trend were included in each equation.

$$DPI_t = f(DPI_{t-1}, SWF_{t-1}, HCR_{t-1}, Q_{t-1}, P_{t-1}, T)$$

$$SWF_t = g(SWF_{t-1}, DPI_{t-1}, HCR_{t-1}, Q_{t-1}, P_{t-1}, T)$$

$$HCR_t = h(HCR_{t-1}, DPI_{t-1}, SWF_{t-1}, Q_{t-1}, P_{t-1}, T)$$

$$Q_t = h(Q_{t-1}, DPI_{t-1}, HCR_{t-1}, SWF_{t-1}, P_{t-1}, T)$$

$$P_t = j(P_{t-1}, DPI_{t-1}, SWF_{t-1}, HCR_{t-1}, Q_{t-1}, T),$$

where

DPI_t = disposable income;

SWF = sow farrowing;

HCR_t = corn price;

Q_t = slaughter;

P_t = hog price; and

T = time trend.

A.12 Bessler and Brandt (1982)

Bessler and Brandt (1982) recently attempted to identify those supply and demand factors that affect hog prices at the farm level and to determine the length of the period occurring between these cause-and-effect relationships. They found that a change in the number of sows farrowing led to a change in hog prices in the opposite direction within the next one to two quarters, which closely relates to the five-to-six-month period required for a pig to reach market weight. Part of the change in price was attributed to producer expectations (e.g., a large number of sows farrowing has a price-depressing effect as meat-packers store less product, reflecting changed price expectations) and part was due to the biological production lag (more offspring being marketed depressing prices). They also found a one-year lag between a price change and a change in the number of sows farrowing. This result tends to agree with the views of many hog industry analysts who suggest that it takes about six months or more of profits or losses before producers will respond by expanding or controlling their breeding herd. The authors also found a rather strong positive relationship between consumer income and hog prices--as income rises, demand increases for pigs.