AN ABSTRACT OF THE THESIS OF


Title: The Public Forage Pricing Implications of Public/Private Market Interdependence

Abstract approved: Frederick W. Obermiller

Market interdependence refers to the influence that administered quantities and/or prices in public forage markets have on private forage market characteristics. The use of a comparable market method to appraise value and price forage resources managed by the Federal Government provides justification for market interdependence research. In this method, private forage markets are used as comparable to Federal forage resources. Two impacts of market interdependence on Federal forage pricing are examined: 1) Violation of a fundamental appraisal assumption, i.e. that the appraised resource does not influence market exchange values; and 2) a violation of sufficient conditions for "piecemeal" pricing, i.e. nonzero cross price elasticities exist between Federal and private markets. To show the existence of market interdependence, changes in private forage market price and quantity are linked to Federal forage quantity reductions. In this research, statistically significant evidence for interdependence is obtained from a case study in Harney County, Oregon. Forage markets are: Alfalfa hay market and Malheur
National Wildlife Refuge grazing program. Both real price and acres of hayland are increased by Refuge forage reductions. Based on ratios of public/private market size, the case study ratio is smaller than the ratio of BLM/FS grazing programs to private grazing land lease markets in the Western United States. Thus, market interdependence in Harney County provides a reasonable basis to infer interdependence between private and BLM/FS grazing land lease markets. It is hoped that a theoretical basis for and statistical evidence of public/private forage market interdependence will promote consideration of this concept in the establishment of Federal (specifically BLM/FS) grazing fees.
The Public Forage Pricing Implications of Public/Private Market Interdependence

by

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For my research in Harney County, Oregon, the Malheur National Wildlife Refuge Manager, George Constantino, was of great assistance in providing access to Refuge grazing program records and a place to stay while conducting my research. Also, permittees who participated in my survey. Their assistance was a tremendous aid to my understanding the influence of market interdependence.

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Prices serve as instruments to coordinate supply and demand in markets for excludable goods (Bos, 1985). This coordination role requires no centralized planning when prices influence both supply and demand. However, in many instances, nonprice considerations determine supply under public sector provision of private (excludable) goods. Examples include timber and livestock grazing on public lands. In these cases, administered prices can fulfill a role of equating demand to supply. Acting as market planners, public sector bureaucrats or politicians may use pricing of publicly provided private goods to equate demand to a predetermined supply.

A "fair market value" mandate for federally owned resources or property (Bureau of the Budget, 1959) can be regarded as a legislative dictate to coordinate supply and demand for private goods provided by the Federal government. For livestock grazing fees on Forest Service (FS) and Bureau of Land Management (BLM) administered lands, this "fair market value" mandate is emphasized by the Federal Land Policy and Management Act of 1976. In this act, Congress declared that:
"the United States receive fair market value of the use of the public lands and their resources unless otherwise provided for by statute" (Sec. 102(a) (9)).

One approach to "fair market value" is simulation of perfectly competitive, market clearing prices where the Federal government provided private goods. Under this approach, an operational definition of "fair market value" is the price at which a good or service provided by the Federal government would be exchanged under competitive conditions (Obermiller and McCarl, 1982). Based on this definition, a comparable market method establishes "fair market value" of publicly provided private goods by using observed prices for similar goods exchanged under competitive conditions. The logic is to use private market data where competitive supply and demand conditions are in operation to develop user charges that resemble as nearly as possible a competitive market value for Federal resources (Secretary of Agriculture and the Interior, 1977).

The comparable markets method has been long advocated as a means of establishing federal grazing fees (Secretary of Agriculture and the Interior, 1977; Voigt, 1976). Comparable market techniques have been followed in studies dating from 1924 (Rachford Appraisal Report) to the latest report on Federal grazing fees (U.S. Department of Agriculture and the Interior, 1986). In both of these studies, estimates of public land forage values are made on the basis of appraisals from comparable private grazing lease arrangements--i.e. public forage values are appraised from observed private grazing lease rates.
Two major problems have been identified with comparable market methods as applied to establishment of BLM and FS grazing fees. They are: 1) Dissimilar goods provided by Federal grazing leases compared with private grazing lease; and 2) interdependence between markets for private and Federal forage. Market interdependence refers to impacts that quantity and/or pricing impacts of private goods provided by the public sector have on observed quantity and price within private markets. For public land forage, private market influences result from nonzero cross elasticities between Federal forage quantities/prices and private forage market characteristics.

Research literature on the first problem has focused primarily on utilization cost differentials between public and private grazing lands. Documentation of higher, nonfee user costs on BLM and FS lands has been well established (Torrell, Godfrey, and Nielsen, 1986; Obermiller and Lambert, 1984; Nielsen and Workman, 1971; Roberts, 1967). Ramifications of this problem have been widely researched and discussed (Nielsen, Godfrey, and Obermiller, 1985; Secretary of Agriculture and the Interior, 1977).

Comparable market appraisals of BLM and FS livestock grazing have dealt with this first problem at various levels. The most comprehensive approach is a thorough user cost accounting in a 1966 survey of private and public grazing land leases in the Western United States (Secretary of Agriculture and Interior, 1977). Results
from that survey found a $1.23 per Animal Unit Month (AUM)\(^1\) differential existed between private lease fee plus nonfee costs and nonfee costs on BLM and FS leases.\(^2\)

This $1.23 differential was judged to be "fair market value" for public livestock grazing. The $1.23 value subsequently has been used to establish FS and BLM grazing fees. It was first used under a program to increase fees to the $1.23 base level between 1968 and 1978. Then, this $1.23 value became a base value for a indexing formula established by the Public Rangelands Improvement Act (PRIA) of 1978 to determine fees between 1979 to 1985. With Executive Order extensions, Federal grazing fees are determined, at present, with this PRIA formula.

The most recent comparable market method incorporates the dissimilar goods argument on a much less comprehensive level. In an appraisal of Federal forage values, the market values of public forage are adjusted by five percent from average private grazing land lease rates to account for different conditions on public land leases (Tittman and Brownell, 1984; p.134). This ambiguous adjustment is calculated from average price differences between non-Federal and Federal land leases (which included competitive leasing on military

\(^1\) An AUM is a quantity measure of forage which usually refers to a forage amount required to support a 1,000 pound cow for one month (Workman, 1986). In some instances, like on the case study of the Malheur National Wildlife Refuge, an AUM refers to a cow/calf pair per month (Johnson, 1988).

\(^2\) Appendix C in Secretaries of Agriculture and the Interior (1977) gives an expanded discussion of how this $1.23 value is calculated from 1966 survey data.
reservations and national wildlife refuges and illegal private subleasing of BLM and FS grazing privileges).

Besides this five percent adjustment from private lease rates, an adjustment for advance payment of federal grazing fees also is recommended (U.S. Department of Agriculture and the Interior, 1986). Based on private lease information, the advance payment adjustment is set at ten percent of appraised public forage value.

Based on the Tittman and Brownell appraisal report, inferred values for public forage range from $4.68 to $8.55 per AUM among pricing areas in the West (U.S. Department of Agriculture and Interior, 1986). These public forage values have not been incorporated into Federal grazing fees. This lack of incorporation mainly comes from political pressure by public land permittees plus criticisms of appraisal methods and interpretations of appraisal results (Nielsen, Godfrey, and Obermiller, 1985).

Contrary to research activity on comparability problems, the interdependence problem has been acknowledged in grazing fee literature but ignored as a research topic (Obermiller, 1984). Clawson (1951) first mentions the concept of interdependent Federal and private forage markets. He notes that such interdependence might occur when "the importance of Federal range in a locality is so great as to materially influence the whole structure of values for surrounding private lands" (Clawson, 1951; p. 10). Obermiller and McCarl (1982) have incorporated Clawson's logic into their argument that private market prices may be neither fair nor efficient when
imposed as administered grazing fees on public lands due to market interdependence.

Recent literature has identified market interdependence as the most damaging criticism of comparable market methods in reference to unknown cross-price elasticities between public and private grazing demand (Taylor and Quigley, 1983). Other authors also have mentioned the dilemma of interdependent forage markets (Upchurch, 1961; Nelson, 1983). However, past research efforts have not investigated the empirical effects of administrative forage quantity/price decisions by the Federal government on prices or quantities in similar private forage markets.

In the absence of corresponding research, public forage value appraisals also have ignored the concept of market interdependence. Neither the 1966 study nor the recent appraisal made any attempt to evaluate interdependence between BLM/FS provision of livestock forage and private grazing land lease markets. The only Federal and private lease connection in these two Federal studies is an assumption used in the 1966 survey of competitive conditions that equate average total (fee and nonfee) forage utilization costs on public and private land (Roberts, 1967).

A lack of research on market interdependence raises a question: How important is this problem in the establishment of fair and efficient public rangeland grazing fees? To address this question, three reasons are postulated for noninvestigation of market interdependence: 1) Research efforts have concentrated on the dissimilar goods aspect of comparable markets; 2) BLM and FS admini-
strators have little incentive to account for this concept in their pricing of livestock forage on public lands; 3) interdependence is a theoretically complex concept subject to little, if any, prior empirical analysis.

The problem of dissimilar goods is easily understood by non-economists. For example, if grazing of livestock on BLM/FS lands has higher nonfee use costs than private land leases, then these two goods are not similar. In addition to this simple logic, a theoretical basis has been established from which to analyze the problem (Roberts, 1967). As earlier referenced, the amount of research effort on the dissimilar goods argument signifies this concept's acceptance as a problem with the comparable markets approach to public forage pricing.

As for the second reason, it is hypothesized in this thesis that BLM/FS administrators have chosen to ignore market interdependence because they wish to use pricing as an instrument to further what they believe is in the public interest—land resource conservation and long-term sustainability of land productivity. In order to insure proper land management under this perceived public interest, BLM/FS bureaucrats use forage pricing to gain control of livestock grazing use on public lands. Such control acts as an enhancement of bureaucratic ability to manage the public land resource. This logic is explored briefly in Chapter V in an attempt to explain why these bureaucratic pricing motivations within the BLM and FS have led to nonconsideration of market interdependence.
Finally, complexity and a lack of empirical evidence have inhibited consideration of market interdependence in determination of federal grazing fees. Two conditions are envisioned as requirements for acceptance of interdependence in the fee debate: 1) Establishment of a theoretical basis for the importance of market interdependence in public resource valuation and pricing; and 2) use of historical, nonexperimental data to prove its existence.

Research Objectives

The aim of this study is to investigate the concept of market interdependence in a manner that can be applied to public land livestock grazing under BLM/FS management. General research objectives are threefold:

1) To establish a theoretical basis for consideration of interdependent market relationships when private market data are used to appraise value or to infer appropriate prices for publicly owned resources;

2) To establish the use of research techniques that can be applied to future interdependence research efforts both within and outside the context of federal grazing fees; and

3) To statistically estimate from historical, nonsimulated data the influence on private forage market prices and quantities from Federal government administrative decisions on livestock forage quantities allocated to private ranches.
Overview of Thesis

Research in this thesis is based on the testing of the null hypothesis that there is no market interdependence between Federal and private forage markets--i.e. that forage quantity decisions by the Federal government do not influence observed characteristics in private forage markets. Before testing this hypothesis, a theoretical basis is outlined in Chapter II as to why market interdependence is important in value appraisal and pricing of publicly owned resources. This chapter also details the research approach taken to test for market interdependence.

Model estimation and testing methods are reported in Chapter III. Models are formulated for testing of the above null hypothesis on both private grazing land lease and alfalfa hay markets. Test locations used in this study are the Pacific Northwest states of Idaho, Oregon, and Washington along with a case study in Harney County, Oregon. Results of model estimation and hypothesis testing with these models are reported in Chapter IV.

In Chapter V, model estimation and testing results are interpreted along with implications for BLM/FS pricing of Federal forage. This chapter also includes a brief explanation of an hypothesized pricing motivation for BLM/FS bureaucrats. This motivation explains why BLM/FS administrators have chosen to ignore market interdependence in pricing of Federal forage.

After interpretation of these results, a normative pricing model is presented in Chapter VI. This model is derived from work by Dreze and Marchand (1976). This chapter's purpose is to examine an
alternative pricing mechanism for BLM/FS forage that does not involve forage value appraisals from private market data. A numerical example using data from Colorado and Idaho shows applicability of this pricing mechanism.

Chapter VII is a summary of this thesis' research findings. The impact of these findings is evaluated for appraisal and pricing of public forage resources with private market data. The influence of market interdependence on various proposed Federal fee systems also is examined.
CHAPTER II
THEORETICAL BASIS AND RESEARCH APPROACH
TO MARKET INTERDEPENDENCE

A theoretical framework and two research approaches are investigated in this chapter to relate provision of livestock forage by the Federal government to private forage market characteristics. The primary emphasis is on livestock forage provided by the BLM and FS. However, both the theoretical framework and research approach can be applied to other public sector provision of livestock forage (such as the case study employed in this thesis, the Malheur National Wildlife Refuge in Harney County, Oregon).

Before theoretical framework and research approach sections, the institutional structure of Federal forage provision is outlined. In addition, arguments are presented for consideration of Federal and private forage supply and demand as separate markets. With this separation, public sector provision of livestock forage is regarded as a Federal forage market. Given separate markets, some distinguishing feature(s) are present in private and Federal forage markets which inhibit the aggregation of supply or demand relationships in single market setting.

Institutional Structure of Federal Forage Provision

The public forage market institutional structures considered in this thesis are forage quantities and prices administratively set by
the Federal government. These institutional structure are, in part, responsible for the existence of market interdependence. These structures function to separate Federal and private forage markets and to provide a means of coordinated quantity and price actions among Federal forage leasing arrangements. The role of market separation is covered in the preceding section.

Coordinated actions across many Federal leasing arrangements are the cause of market interdependence. While required for market interdependence, a large amount of Federal forage provision is not a sufficient condition for existence of interdependence. It is a coordinated action among these leasing arrangements that creates interdependence. As an example of how size is a sufficient condition, market interdependence would not exist even with a large number of Federal leases in an area if Federal forage provision as done independently among leases, i.e. competitive bidding of individual Federal leases with no connection between leases.

For the BLM/FS, coordinated actions on forage quantities are done at local BLM district and FS National Forest levels. These quantities are allocated to holders of Federal permits. Federal grazing permits are tied to ownership of specific private property or water rights (also cattle brands for the FS). Owners of these private properties have the privilege of grazing their livestock on public land. By following permit rules and regulations, Federal grazing permits are, in practice, continually renewed to these private property owners every ten years. Forage quantities allocated
are based on historical livestock use for each permit and on livestock carrying capacity of the public rangeland.

Price establishment by the BLM/FS is coordinated on a nationwide basis. The same grazing fee per AUM is charged on all BLM and FS lands (except for National Grasslands). As mentioned previously, the current Federal grazing fee is set by a formula established in PRIA. In this formula, the $1.23 base "fair market value" is indexed by three indices: (1) a forage value index from private grazing land leases; (2) a livestock price index; and (3) a cost of livestock production index (Obermiller, 1984).

With expiration of the PRIA formula in 1985, many other Federal grazing fee systems have been proposed (Brokken and McCarl, 1987; U.S. Department of Agriculture and the Interior, 1986). Brokken and McCarl (1987) list three types of Federal grazing fee systems that are most successful in meeting fee evaluation criteria: (1) Fee formulas such as the PRIA formula; (2) competitive bidding; and (3) cost of administration. The present Federal forage institutional structure accommodates each fee system except for competitive bidding. To implement competitive bidding, legislative action would be required to change the present structure.

Separation of Federal and Private Markets

A market is a set of arrangements for bringing buyers and sellers together to discover terms of trade for exchanges (Boyce and Kinnard, 1984). Terms of trade include goods, services, rights, and money. If one is to recognize Federal and private forage markets as
being separate, forage products and institutional arrangements under which transactions occur must differ substantially between markets. In this section, institutional market structure and product differences are the reasons for a separation between BLM/FS forage and private grazing lease markets.

Restrictions on buyers of Federal forage are the primary institutional structure which distinguishes this market from private forage markets. Authorized participants in BLM/FS forage markets, and some other Federal forage markets, are restricted to holders of permits or leases issued by the Federal government. As mentioned in the previous section, Federal grazing permits are continually renewed to the current holders. Thus, authorized market participants are very restricted in the short run.

One method of short-term market entrance into BLM or FS forage markets is to illegally sublease from present permit holders. However, these participants are not recognized as legitimate market participants. Nor are their grazing use rights enforceable.

In order to become a legitimate market participant in BLM/FS forage markets, entrance requires a substantial capital investment. Participants must either purchase a permit/lease or the associated private "base" property. For purchase of grazing permits only, average BLM/FS permit value in the Western U.S. is about $70 per head
month\(^1\) (U.S. Department of Agriculture and Interior, 1986). In Eastern Oregon, a recent study has found average BLM and FS permit values to be $44 and $62, respectively (Obermiller and Collins, 1986). Over a typical three month summer grazing season on FS land in Eastern Oregon, the corresponding totals over $180. This total is the amount a permittee must invest for the privilege to graze and pay federal grazing fees for one cow on Forest Service lands. This substantial investment requires long-term commitments which make market entrance or exit difficult.

A product differentiation concept is the second reason for Federal and private forage market separation. Under this concept, distinguishing features among products create an inability to substitute between them (Bain, 1968). For BLM/FS forage markets as compared with private grazing leases, some differential features include: a) Nonfee user costs (livestock death loss is an example); b) forage quality and quantity; c) lease rules and regulations governing grazing use; d) restrictions on other land uses, such as

\^[1]\: The classical argument for a source of permit value is a discounted stream of future returns from Federal forage being priced under its value for livestock grazing (Nielsen and Workman, 1971). Based on this classical argument, an annual value can be placed on Federal forage from observed permit values. Gray (1982) has proposed that federal grazing fees be calculated from permit values. Drawbacks to the use of permit value to price Federal forage include: a) a dispute over source of permit value ("license to ranch" arguments by Obermiller and McCarl (1982)); and b) Federal land management implications of government's legal recognition of permit value (Collins, 1980).
recreation; and e) livestock grazing services provided by the lessor (salting or maintenance of water/fence improvements, etc.).

Except for nonfee user costs, the significance of these differences in public and private lease products has not been thoroughly researched and is subject to debate. As an overall generalization, BLM and FS permits tend to have much more restrictive regulations regarding livestock numbers and allowable use period. These livestock restrictions are coupled with fewer restrictions on allowance of nonlivestock grazing uses of public compared with private rangeland. A comprehensive survey of private grazing land leases in the western U.S. reveals a wide variety of livestock services offered in private lease agreements (Tittman and Brownell, 1984). Conversely, BLM and FS permits offer a standard level of lessor services--practically none except for help in development of rangeland improvements.

In summary, BLM/FS provision of livestock forage constitutes a separate market compared with private grazing lease markets. The reasons for this separation are entrance restrictions on BLM/FS market participants, distinctly different forage lease products, and dissimilar terms and conditions in lease arrangements. Because these forage markets are both separate and different, aggregation of public and private supplies into one market supply function is an incorrect approach to assess the influence of BLM/FS market decisions on prices or quantities observed in the private forage market.

2 For an excellent discussion of these differences, see Section 3 of the Federal grazing fee report by the Secretaries of Agriculture and the Interior (1977).
**Theoretical Framework for Market Interdependence**

The theoretical framework for valuation and pricing of Federal forage is an objective to maximize social welfare. It is assumed that individual utility functions measure social welfare. Acting as "planners" within the Federal forage sector of the economy, BLM/FS bureaucrats are assumed to value and price Federal forage to promote social welfare.

Use of this theoretical framework does not imply that social welfare maximization is the sole pricing objective of the BLM or FS. Rather, this framework is meant to show that market interdependence is a problem when employing private forage market data to maximize social welfare under an idealized pricing situation.

Two pricing examples are provided in this section of how market interdependence influences valuation and pricing of Federal forage. The first example considers optimal forage valuation and interdependence under a simple, general equilibrium model derived from Davis and Whinston (1965). This model uses the Theory of Second Best (Lipsey and Lancaster, 1956) as a normative pricing objective for Federal forage. In the second example, market interdependence is examined for its impact on the achievement of Pareto optimal, first best pricing of Federal forage resources.

**Second Best Pricing Model**

A second best, general equilibrium model is set up to show the influence of market interdependence on forage valuation and pricing decisions by Federal bureaucrats. This influence occurs when private
market data are used to appraise Federal forage value and then price this forage based on appraisal results. In this model, Federal forage pricing decisions are made by bureaucratic planners to maximize social welfare given that decentralized decision-making occurs within the rest of the economy. The model becomes a second best problem when Federal restrictions on market participants are included as a constraint. This constraint arises from an earlier Federal market separation argument.

Using vector maximization of the objective function, the second best model is:

\[
\text{Max } [U_1(x_1), \ldots, U_m(x_m)]
\]  

\[\text{Subject to }\]

\[
\sum_{i=1}^{m} x_{ik} \leq \sum_{r=1}^{Z} y_{rk} \quad k = 1, \ldots, n
\]  \hspace{1cm} (2.2)

\[g_r(y_{r1}, \ldots, y_{rn}, h_{r1}, \ldots, h_{rns}) \leq 0 \]

\[r = 1, \ldots, z\]  \hspace{1cm} (2.3)

\[
\sum_{k=1}^{n} \sum_{r=1}^{Z} h_{rj} \leq H_j \quad j = 1, \ldots, s
\]  \hspace{1cm} (2.4)

\[h_{rbf} \leq H_{rf} \quad r = 1, \ldots, w \quad w \leq z\]  \hspace{1cm} (2.5)

\[x_{ik}, y_{rk}, h_{rkj}, h_{rkf} \geq 0 \text{ all } i, r, k, j, f.\]  \hspace{1cm} (2.6)

The following definitions apply:

\[U_i = \text{utility function of the } i^{\text{th}} \text{ of } m \text{ individuals;}\]
\[ x_{ik} = \text{quantity of the } k^{th} \text{ of } n \text{ goods consumed by } i^{th} \text{ individual}; \]

\[ X_i = \text{bundle of goods consumed by } i^{th} \text{ individual}; \]

\[ y_{rk} = \text{quantity of } k^{th} \text{ good produced by } r^{th} \text{ firm}; \]

\[ g_r = r^{th} \text{ of } z \text{ firms transformation function}; \]

\[ h_{rkj} = \text{quantity of } j^{th} \text{ resource used by } r^{th} \text{ firm to produce } k^{th} \text{ good}; \]

\[ h_{rbf} = \text{Federal forage (f) allotted to produce beef (b) by } r^{th} \text{ firm (permittee ranch)}; \]

\[ H_j = \text{available quantity of } j^{th} \text{ resource}; \]

\[ H_{rf} = \text{Federal forage allocated to } r^{th} \text{ permittee ranch.} \]

Equations (2.2) through (2.4) are no excess demand, production possibilities,\(^3\) and resource availability constraints, respectively. Along with a non-negativity requirement of (2.6), these equations are typical constraints in a general equilibrium system to solve for Pareto optimal conditions (Davis and Whinston, 1965). The additional constraint of Federal forage assigned to individual ranches, equation (2.5), stems from Federal market constraints as they occur under BLM/FS grazing permit allocation procedures.

\(^3\) To simplify development of this model, an assumption is made that firms are single output and/or have linear production functions. With this assumption, inputs are assigned to specific outputs. Use of this assumption does not change pricing or valuation decisions in Federal forage market.
To solve for a maximum in this model, a Lagrangean function is formed from equations (2.1) through (2.5). The model becomes a constrained nonlinear optimization problem. Using Kuhn-Tucker techniques, first-order conditions are solved for a maximum to (2.1). First-order conditions for input use in beef production are:

A) Federal forage:

\[- b * \frac{\partial g_r}{\partial h_{rbf}} - d_{rf} = \text{if } 0 < h_{rf} \leq 0 \quad (2.7)\]

\[ r = 1, \ldots, w \]

B) All other inputs except Federal forage:

\[- b * \frac{\partial g_r}{\partial h_{rkj}} - \bar{c}_j = \text{if } h_{rkj} > 0 \quad (2.8)\]

\[ j = 1, \ldots, s \quad k = 1, \ldots, n \quad r = 1, \ldots, z. \]

In (2.7) and (2.8), \( \tilde{b}, \tilde{c}, \) and \( \tilde{d} \) are multipliers from constraints (2.3), (2.4), and (2.5), respectively. These multipliers measure cost of these constraints and can be interpreted as prices (Davis and Whinston, 1965). From (2.7) and (2.8), ratios of optimal input use are different for each individual permittee:

\[ \frac{\tilde{c}_p}{d_{rf}} = \frac{\partial g_r}{\partial h_{rbp}} \quad r = 1, \ldots, w \quad p = \text{private lease grazing} \quad (2.9) \]

\[ \frac{\tilde{c}_t}{d_{rf}} = \frac{\partial g_t}{\partial h_{rbt}} \quad r = 1, \ldots, w \quad t = \text{all other inputs in beef production} \quad (2.10) \]
Following the first fundamental theorem of welfare economics (Boadway and Bruce, 1984), decentralized decision-making under a competitive market system creates conditions for a solution set of Pareto optimal prices equal to all the above multipliers except for \( \tilde{d}_{rf} \). Because of constraint (2.5) in maximization of societal welfare, a second best optimum is achieved if Federal forage can be priced at individual permittee use values (\( \tilde{d}_{rf} \)) to create an equality in Equation (2.7). One way for social welfare maximizing bureaucrats to achieve this second best optimum is to administratively set federal grazing fees at \( \tilde{d}_{rf} \).\(^4\)

If long run, competitive equilibrium conditions are assumed to hold in the Federal forage market, second best optimum prices would be equal to Pareto optimal, first best prices. Forage use values to individual permittees (\( \tilde{d}_{rf} \)) would be identical, and if Federal and private grazing leases are perfect substitutes, all \( \tilde{d}_{rf} \) would equal \( \tilde{c}_{p} \). However, second best pricing should differ from first best pricing as \( \tilde{d}_{rf} \) do differ among permittees. Part of the reason for different use values is attributed to the Federal grazing permit allocation system. By nonprice allocation to ranchers who may not be able to secure permits under conditions of competitive bid, the

\(^4\) BLM and FS regulations which provide for transfer of permits do break down, to some degree, market participant restrictions of (2.5). By authorizing permit transfers, competitive market forces are allowed to enter into determination of allocations with a resultant movement towards Pareto optimum allocations. However, Gardner (1962) has noted that BLM/FS permit regulations still result in transfer restrictions which cause in a loss of value on public grazing permits that is not captured by any party.
Federal allocation system does prevent occurrence of a long run, competitive equilibrium.

Market interdependence becomes an important aspect in second best pricing when estimates of \( d_{rf} \) use private market data.\(^5\) Estimation of \( d_{rf} \) with private forage market exchange values (\( c_p \)) is complicated by many factors other than interdependence (Obermiller, 1984). Market interdependence, however, adds another complication to a use value appraisal by violation of a fundamental assumption of appraisal theory. This assumption is that an appraised resource has no or at least minimal influence on the exchange value used to appraise, here, use value to the permittee.

Appraisal is a supportable and defensible estimate of value, usually exchange value (Boyce and Kinnard, 1984). Except for the caveat that market value must be determined in an open, competitive market, modern appraisal techniques do not cover the possibility that transaction of a resource at its appraised value might influence exchange value in the market judged to be comparable (Boyce and Kinnard, 1984; American Institute of Real Estate Appraisers, 1983; Suter, 1974; Murray, 1969).

Only Bonbright (1937) addresses the issue of transaction of an appraised resource influencing exchange values. Bonbright recognizes what he called an imputed market value as price per unit times number of units in a sale. He notes that a possibility exists for imputed

\(^5\) If Federal and private grazing leases are perfect substitutes, one uses \( c_p \) directly. As occurs with BLM/FS forage, adjustments of \( c_p \) must be made for differences in items like user costs.
market values to differ from actual sale price. This difference occurs when the quantity of an appraised resource is of sufficient size that its transaction affects price per unit received for the entire resource sold. However, Bonbright (1937) does not attach much significance to a distinction between imputed and market values for appraisal purposes. In addition, he points out that imputed market value has been upheld by courts as "fair market value" for inheritance tax purposes.

Despite Bonbright's dismissal, market interdependence should become a concern to BLM/FS bureaucrats under second best pricing. A violation of the fundamental assumption of appraisal means that quantity of Federal forage supplied and the demanders in the Federal market are of sufficient size to influence observed private grazing lease market characteristics. Thus, if Federal market restrictions on participants are dropped and Federal supplies and demanders are included in the private market, equilibrium exchange value and quantity would differ from present market characteristics (Figure 1). In the Figure 1 example, a combination of Federal and private forage markets results in a higher price \( P_1 \) than observed second best price \( P_0 \) in the private market.

Therefore, a violation of the fundamental appraisal assumption occurs when two different \( c_p \) can exist: 1) A \( c_p \) that exists under the present second best restrictions conditions; and 2) a \( c_p \) that would occur if the Federal market was included into private forage markets. The possibility of different \( c_p \) depends on an assumption that, without the second best restrictions, additional Federal mar-
Figure 1. Pareto Optimal ($P_1$) and Second Best Optimal ($P_0$) Prices in the Private Market when Federal and Private Grazing are Perfect Substitutes,* without versus with Federal Market Constraints.

* If grazing resources are not perfect substitutes, then more than one market exists due to different products. Lifting of Federal constraints in this case alters slopes of private market demand and supply functions.
ket supply and demand would not balance each other out when combined with private markets. Since under both second best restrictions and no restrictions (Pareto optimal conditions) optimal pricing is determined by ratios, the most that one can say about these possible \( c_p \) values is that second best \( c_p \) is probably not equal to a \( c_p \) determined under no Federal market restrictions.

The most appropriate use value estimate of \( c_p \) is judged to be the second one, that which occurs under conditions of Pareto optimum. The logic is that use value would then be determined with both the Federal forage resource and its demanders combined with private market supply and demand to evaluate exchange value. Thus, private forage market exchange value best approximates Federal forage use value when Federal supplies are included in the private market. If market interdependence does not exist, the combination of Federal and private markets has no influence on exchange value. However, with market interdependence, exchange value is altered by addition of the Federal market to the private market.

With use value most appropriately determined by combined markets, the size of Federal markets, e.g. the BLM/FS grazing program, in an area becomes important as compared with local private forage markets. For example, BLM/FS forage resources represent only about eight percent of total rangeland forage, both leased and non-leased, from a national forage market perspective (U.S. Department of Agriculture and Interior, 1986).

On a regional and local scale, however, Federal lands can dominate forage markets. In 17 Western States, BLM/FS managed lands
are significant compared with private grazing land leases. Over the entire region, a survey of rangeland leasing covering 80 to 90 percent of all lease transactions found 103.5 million acres of rangeland are leased by parties other than the BLM and FS (Tittman and Brownell, 1984). This acreage figure compares with over 300 million acres of leased public rangeland administered by the BLM and FS (U.S. Department of Agriculture and Interior, 1986). Even with private rangelands being generally more productive, BLM/FS resources represent a substantial portion of forage leased in the western U.S. While this proportion varies greatly at state and county levels, BLM/FS grazing can represent an even greater proportion of rangeland leasing than figures throughout the western U.S. suggest.6

Given the above Federal/private comparisons, private grazing land lease markets in many state and local areas undoubtedly are influenced by the addition of BLM and FS forage supplies and their demanders. Thus, observed prices from most Western state and local grazing land lease markets have to be considered dubious estimates of use value in BLM/FS forage markets without inclusion of Federal supplies and their permitted users.

**First Best Pricing**

Under first best pricing, BLM/FS bureaucrats would choose to ignore Federal market restrictions and to price Federal forage with Pareto optimum exchange values. From a Pareto optimal standpoint,

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6 Examples include the state of Nevada and Harney County, Oregon where 82 and 73 percent of land is managed by the Federal government, most by the BLM and FS (Fairfax, 1987; Valde, 1973).
pricing Federal forage at marginal cost maximizes social welfare. In this instance, observed private forage market prices act as an approximation of Pareto optimal, marginal cost pricing for Federal forage. This approximation is based on an assumption that private market prices reflect marginal cost pricing for livestock grazing. Thus, BLM/FS bureaucrats establish federal grazing fees based on private market prices to achieve Pareto optimal prices in the Federal market.

Bureaucratic pricing of Federal forage at marginal cost is an example of a "piecemeal" approach to pricing. A "piecemeal" pricing approach is taken when attempting to fulfill conditions of Pareto optimality in one sector of the economy without regard to other sectors (Boadway and Bruce, 1984). For instance, this approach is taken when only Federal grazing fees are changed to meet Pareto optimum conditions while leaving permit transfer restrictions unchanged.

"Piecemeal" pricing, however, is adversely affected by market interdependence between Federal and private forage markets. Such a pricing policy is not an appropriate policy because existence of interdependence violates sufficient conditions for first best pricing as set forth by Boadway and Harris (1977). These conditions require zero cross-price elasticities of uncompensated demand and supply functions between distorted Federal forage markets and undistorted private forage markets. Nonzero cross-price elasticities clearly are violated when Federal and private forage markets are interdependent.


**Research Approach**

Despite the extent of Federal lands in the western United States, there is a definite lack of research on and recognition of the market interdependence relationship in Federal resource pricing. The absence of research applies for livestock grazing as well other uses of natural resources like timber and outdoor recreation. Several studies do investigate pricing of Federally controlled natural resources and have relevance to market interdependence. However, research methods of these studies generally are not applicable to forage markets.

Two studies from the forestry literature are applicable to interdependent markets. One research study uses Granger causality methods to analyze the influence of timber sales on National Forests on timber and lumber prices (Buongiorno, et al., 1985). This study did not find evidence that knowledge of past, current, and future volumes offered influenced current wood prices.

Granger causality methods are not included in this research for two reasons: 1) It is strictly a data based technique with no theory of causation to back up postulated relationships; and 2) probably stemming from the first reason, specification error has been suggested as a major problem with Granger causality testing of economic time series data (Blank and Schmiesing, 1986).

In the other forestry study, Clawson (1985) uses computation of inflation index procedures and statistics to speculate about a level of interdependence between Federal timber prices and consumer prices. He links a ten percent rise in national forest stumpage price to as
much as an one percent rise in the U.S. inflation rate, given second and third-round effects resulting from this housing input price rise. With the amount of speculation involved with Clawson's research approach, his methods are not applicable in this research.

In the outdoor recreation market, one study has investigated public/private market links. Reiling (1976) postulates a negative influence on returns to private campground businesses from underpriced public campgrounds. Reiling does find expected low returns to investment capital in the Oregon coast private campground industry to support this hypothesis. Besides budgeting methods, Reiling uses a survey of private campground operators to show that they generally view public facilities as being competitive with their enterprise. His methods do not, however, establish direct influences of quantity or price between public and private markets. These direct influences are the focus of this research on market interdependence.

Given inadequacies of the above approaches to interdependence, two approaches are explored to relate Federal/private forage market interactions. Both approaches use demand-supply concepts to explain private market price and quantity. These approaches relate Federal policy decisions to both demand and supply in private markets.

**Adaptations to Resource Endowment Changes**

In this approach, quantity decisions in Federal forage markets have direct influences on demand/supply in private forage markets. These influences come from management adjustments taken by permittee
ranch operations in response to quantity changes in Federal grazing permits.

This approach is best explained by a couple of examples: 1) As one alternative to a cutback in permitted use on a BLM or FS grazing allotment, increased demand in the private grazing lease market occurs as permittees attempt to maintain herd size by replacing seasonal public grazing lost to the ranch operation with private grazing leases; and 2) reductions in winter grazing on Federal land stimulate the development of more hayland on a ranch operation, which results in a larger private land hay supply even though this hay may not be sold regularly in the private hay market. The result is that Federal market decisions are transferred into private markets by aggregate demand or supply shifts depending upon how most permittees respond to a cutback in permitted Federal land grazing use.

This approach regards Federal market quantities as ranch resource endowments. For the BLM and FS, endowment logic comes from grazing permit allocation procedures detailed previously in market separation section. Based on this research approach, permittee adjustments to these endowment changes are the mechanism from which altered private forage market prices and quantities.

An illustration of this approach to interdependence is shown in Figure 2. This figure is an expansion of the interdependence concept presented in Figure 1. Quantity reductions in the Federal market cause an aggregate private market demand curve shift to the right (D₀ to D₀*). The result is a higher private market price (P₀*) given the existing second best constraints.
Figure 2. Private Forage Market Demand Shift from Federal Forage Market Quantity Reductions Resulting in a Higher Equilibrium Price $P_0^*$ in Private Market.
Changes in Market Structure

The second approach relates demand structure in private forage markets to Federal grazing allocation policy decisions. Here, interdependence is between private grazing land lease market demand and a BLM/FS policy of commensurability for permitted livestock grazing use. Under this Federal grazing use requirement, permittees must own land resources sufficient to feed livestock during seasons when they are not using public rangeland. Thus, commensurability helps create seasonal forage balance among permitted ranch operations.

If demand in private grazing land lease markets is composed largely of seasonal demands to balance out a ranch operation's livestock forage needs, then observed demand should be lower where ranches were formed under commensurability requirements than in private lease markets where ranches did not have this requirement. In an area with a large amount of public land, like Eastern Oregon, this requirement could materially lessen private market aggregate demand compared with conditions of no commensurability requirements.

This approach is close to a test for a significant difference between $P_0$ and $P_1$ from Figure 1. However, this approach considers not so much quantity of BLM/FS supplied forage as it does how these markets' requirements have shaped private market demand functions. To evaluate interdependence under this approach, an examination would be made of comparable private markets with varying amounts of BLM/FS livestock grazing nearby (i.e. within the same county). The
objective would be to investigate influences on private market prices from various levels of Federal commensurability requirements.

Research under this approach requires extensive cross-sectional data on private forage market transactions. An example of adequate cross-sectional data is the private grazing land lease information collected during the 1966 survey mentioned earlier. Williams (1969) uses this survey data to define private grazing land lease market areas for each National Forest. His findings plus BLM/FS livestock grazing quantities form a data base for interdependent markets modelling. Chi-square classification table testing is one possible technique that could be used to compare similarities between total use cost of grazing in private lease markets and Federal market forage supplies.

Selected Approach

To test for market interdependence, the first research approach of adaptations to resource endowment change is selected in this study. Three considerations are important in this decision: 1) The first approach postulates a direct impact of public decisions on private markets compared with an indirect connection in the second approach; 2) the commensurability influences on private market demand structure were created many years ago, making these influences difficult to separate out from other market changes over time; and 3) recent available data are not comprehensive enough to do cross-sectional comparisons of private grazing lease markets.
By direct testing with the first approach, recent Federal market quantity decisions are related explicitly to observed private market prices and quantities. Direct testing is judged to be preferable to a structural approach which would evaluate indirect influences from BLM/FS policies imposed initially on their forage market participants.

As for the second consideration, formation of BLM and FS forage markets with permit allocation took place years ago—-in the early 1900s for the FS (Rowley, 1985) and during the mid to late 1930s for the BLM (Klemme, 1984). In both cases, a rancher’s ability to prove commensurability was an important, but not sole, feature in determining who received livestock grazing permits.

Since formation of these Federal forage markets, many other influences have affected the structure of demand in private markets, e.g. improvements in hay production technology. Such influences are difficult to differentiate when comparing Federal land versus nonfederal land influenced markets. In addition, evidence of the effects from recent Federal market quantity decisions is judged to be much less complicated to model and test for the existence of market interdependence than long established Federal market constraints.

Third, information from a 1966 survey of private grazing land leases does form an adequate data base to make cross-section lease comparisons. Recent lease data collected for appraisal of value for BLM/FS forage, however, do not include important items such as cost of lessor services (Tittman and Brownell, 1984). Without adequate
control for cost differences, cross-section comparability of leases is meaningless.

The selection of the first research approach, allows for the use of historical data to show market interdependence. Since the purpose of this research is to elevate the concept of market interdependence in decision-making on federal (particularly BLM/FS) grazing fees, statistical proof by historical data is important.

A comparison to prior hypothesis testing done by Roberts (1967) illustrates the importance of testing for market interdependence with historical data. His research showed statistical evidence from Utah grazing lease markets that grazing use costs are equal between private and public grazing leases. Roberts' cost equalization theory now forms a basis for the dissimilar goods argument of comparable markets approach. An effect similar to Roberts' impact is envisioned for market interdependence from this research.

The use of historical data in the first research approach does negate a direct test of market interdependence within the second best theoretical framework set up earlier, i.e. violation of the fundamental appraisal assumption. Since there are no historical data on aggregation of public and private forage markets (for example, large scale privatization of public grazing lands), the issue of different observed exchange values with combined markets is not directly addressed in this research. It is postulated, however, that statistical evidence supporting interdependent markets under the first research approach translates into a reasonable, subjective evaluation that exchange values change with combined markets. Thus,
if resource endowments of the Federal market are reduced, statistically significant changes result in private market price and quantity. Under this situation, Federal market size is sufficiently large to impact private market exchange value if markets are combined.

Finally, the first research approach shows that sufficient conditions for first best pricing do not hold. The requirement of nonzero cross price elasticity means that quantity demanded in the private forage market \( q^d_{\text{priv}} \) is affected by federal grazing fees \( p_{\text{fed}} \). Past federal grazing fees have been established in relation to private lease rates. This feature of federal grazing fee establishment prevents a direct inference of significant relationship between \( q^d_{\text{priv}} \) and \( p_{\text{fed}} \) because of a relationship between private forage market price and quantity demanded. To establish a nonzero cross price elasticity, the following causality relationships are assumed:

\[
q^d_{\text{priv}} = f(p_{\text{priv}}; p_{\text{fed}}) \quad (2.11)
\]

\[
p_{\text{priv}} = f(q^d_{\text{fed}}) \quad (2.12)
\]

\[
q^d_{\text{fed}} = f(p_{\text{fed}}) \quad (2.13)
\]

where:

\[
p_{\text{priv}} = \text{private market forage price;}
\]

\[
q^d_{\text{fed}} = \text{quantity of Federal forage demanded; and}
\]

\[
p_{\text{fed}} = \text{price of Federal forage.}
\]
By showing that (2.12) and (2.13) are statistical relationships, \( p_{fed} \) is inferred to have a nonzero relationship with \( q^d_{priv} \). This relationship stems from \( p_{fed} \)'s influence on \( q^d_{fed} \) (2.13) and then \( q^d_{fed} \) influence on \( p_{priv} \) (2.12). Thus, \( p_{fed} \) influence comes as a result of \( p_{priv} \) impact on \( q^d_{priv} \).

In this thesis, equation (2.12) is established by model estimation and testing. Johnson and Watts (1988) have already shown (2.13) to be a statistically significant relationship for the BLM forage market. A combination of statistically significant relationships from both this thesis and Johnson and Watts results are used to conclude nonzero cross price elasticity in Federal and private forage markets.
CHAPTER III

RESEARCH METHODS AND DATA

This chapter begins with a brief overview of research procedures and descriptions of two Federal forage markets investigated in this thesis. Then, research methods and collected data are presented for three models formulated to test for the existence of Federal/private forage market interdependence.

Progression of Thesis Research

The purpose of this section is to explain the logic behind a progression of research from BLM/FS Federal forage markets to the Malheur National Wildlife grazing program. Part of the intrigue of any research project is the unknown pathways that exploration of a largely unresearched idea, like forage market interdependence, can take. Despite well laid out plans of action, the process of inquiry becomes quite unexpected as research "deadends" down one path lead to explorations of other means to show the existence and effects of the phenomenon being studied. This thesis is a good example of what unanticipated pathways can result from initial rejection of hypotheses.

A final version research outline of this thesis implicitly requires that results be revealed ahead of research methods. This unconventional presentation of information is done in Table 1 to provide an overview of steps leading to a successful final test of forage market interdependence in Harney County, Oregon.
Table 1. Research Pathways During Development of This Thesis.

Model A - State Grazing Land Lease Markets

Public Market: BLM and FS livestock grazing programs.

Private Market: Grazing land lease.

Location: Northwest states of Idaho, Oregon, and Washington.

Methods: Linear model using seemingly unrelated regression with aggregated data by state to explain private lease rate changes with changes in BLM and FS permitted livestock grazing.

Model B - Harney County Forage Land Lease Market

Public Market: Malheur National Wildlife Refuge’s livestock grazing and haying program.

Private Market: Grazing/haying lease market of land comparable to Refuge property.

Location: Harney County, Oregon.

Methods: Simultaneous equation system which includes one equation to explain private land lease rates as a function of quantity of livestock forage offered by the Refuge.

Model C - Harney County Alfalfa Hay Market

Public Market: Malheur National Wildlife Refuge’s livestock grazing and haying program.

Private Market: Alfalfa hay market.

Location: Harney County, Oregon.

Methods: Regression equations to explain how Refuge management policy has affected development of alfalfa hay production acreage and alfalfa hay price.
Failure to show market interdependence from BLM and FS forage markets is attributed to a couple of problems: 1) Too much aggregation in the available state level data; and 2) a lack of dramatic reductions in BLM and FS permitted grazing use within an area where private lease market data are available. These data problems are closely tied to each other and together act to prevent a meaningful evaluation of market interdependence. These problems are explored further in Chapter V under interpretations of results.

A case study area of Harney County, Oregon, is chosen in order to investigate an area where Federal land management policies resulted in substantial quantity reductions in a public forage market. These reductions occurred during the 1970s in a Federal forage market located in this county--the Malheur National Wildlife grazing and haying program. As explained in the next section, evidence for market interdependence from a public forage market is expected to be present when a large seasonal supply of forage is dramatically reduced by management policy as occurred on the Refuge.

**Description of Public Forage Markets**

Grazing programs for the BLM/FS and the Malheur National Wildlife Refuge are reviewed in this section. Their institutional structures and their influence of market interdependence are described. A change in resource endowment approach is used to examine market interdependence.
BLM and FS Grazing Programs

Under the first research approach, market connections are assumed between BLM/FS quantities available and observed prices in private grazing land lease markets. Reductions in BLM/FS grazing create increased demand for grazing land leasing as permittee substitute private leases for Federal permits. Increased demand then leads to higher lease rates. By this causal mechanism, market interdependence is assumed to be observable.

Livestock grazing use on BLM/FS public lands has declined substantially from use levels during early periods of public land administration (Clawson, 1967). Declining grazing use on western public lands has continued into the 1960s and 1970s (Godfrey, 1979). Despite these declines, neither the BLM nor FS have now or have ever had "official," agency-wide policies of reducing livestock grazing on public lands.

BLM adjudication is the closest to an "official" reduction policy on these Federal lands. Between 1950 to 1967, adjudication included estimations of rangeland carrying capacities and then proposed reductions of livestock numbers where current use was greater than capacity (Nelson, 1980). Due to initial overallocated public rangelands, adjudication reductions were substantial, but often included reductions on nonutilized permits (Foss, 1960). Because of adjudication, statewide BLM grazing use declined from 20 percent in California to 40 percent in Utah between 1946 and 1964 (Nelson, 1980).
Other BLM/FS reductions of livestock numbers stem from: a) Ownership transfer of FS grazing permits (Gardner, 1962); b) reducing use when changes occur in permit livestock class from sheep to cattle (Godfrey, 1979); and c) proposed reductions of use in recent Environmental Impact Statements (EIS) of livestock grazing on public lands.\(^1\) All these actions which reduce BLM/FS grazing have one element in common: They originate from decision-making at local BLM District or FS National Forest levels. Determination of BLM/FS grazing reduction policies at a local level rather than state or nationwide becomes a problem for model coefficient estimation when data are available at state levels. As explained previously, the reasons for this problem are explored further in Chapter V.

Except for year-long grazing in the southwest, most livestock use on BLM and FS land occurs from spring through fall in the 11 Western states. Thus, quantity reductions in these public markets result in seasonal forage deficits for ranches with Federal permits. Federal quantity declines then are assumed to be transmitted to private grazing land lease markets. This connection between markets stems from the hypothesis that leasing private rangeland is the most common permittee ranch adjustment to forage reductions when forage resources outside of those already present on permitted ranches are used to substitute for lost Federal forage.

Leasing of private rangeland is but one response to cutbacks in permitted grazing use on BLM and FS land. A small survey of FS

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\(^1\) Nelson (1980) notes that few EIS proposed grazing use reductions have occurred and those permits that have had livestock cuts were with ranchers consent.
permittees in Oregon reveals primary ranch operation adjustments under hypothetical cutbacks to be: 1) Livestock herd reduction; 2) leasing private pasture; and 3) adjustment in hay buying/selling (Quigley, et al., 1986). Of these alternatives, typical ranch research shows leasing to be more favorable than herd reduction or buying hay because leasing results in less lost income (Olsen and Jackson, 1975; Kearl, 1964; BLM, 1962). Thus, increased private grazing land leasing is a reasonable adjustment to Federal permit quantity reductions.

Malheur National Wildlife Refuge Grazing and Haying Program

The Malheur National Wildlife Refuge is located in Harney County, Oregon (Figure 3). The Refuge was established in 1908 as a preserve and breeding ground for native birds, livestock grazing on the Refuge has been an important management tool to remove excess forage growth from flood irrigated pastures since World War II. Most livestock grazing use occurs in the form of rake-bunch grazing. Under this grazing system, harvested forage from irrigated areas is bunched in piles, and grazed from October through January. Only recently, a limited amount of hay has been harvested and taken off the Refuge.

Much like BLM and FS grazing, Refuge permits for grazing and haying are assigned to individual ranchers on a continuous basis. Permit price per AUM and allocated quantity also are set by Refuge administration. Unlike BLM and, to some extent, FS markets, Refuge
Figure 3. Location of Malheur National Wildlife Refuge and Harney County, Oregon.
permits are nontransferable and carry no guaranteed area or minimum level of use.

Permitted grazing use on the Refuge has ranged from 110 and 120 thousand AUMs during the 1960s and early 1970s (Figure 4). During this period, Refuge forage provided a significant quantity of cattle feed in Harney County—between 25 and 30 percent of total November to March cattle feed requirements for the County. A change in Refuge management during 1973 along with predator control restrictions on the Refuge, however, led to substantial reductions in Refuge livestock grazing during the 1970s.

These reductions occurred from cutting the quantity of permitted AUMs on existing permits and from cancelling permits when ranch operations were sold or the owner passed away. Permitted use finally stabilized around 40,000 AUMs in the mid-1980s (Figure 4). When the Refuge management policy of reducing grazing ended in 1981, quantity reduction had totalled roughly 70 percent of the amount of forage used by permittees in 1973. This substantial reduction is what makes the Malheur National Wildlife Refuge an ideal case study to test for market interdependence between the Refuge and other forage markets in Harney County.

Since the Refuge provides late fall and early winter forage to permittee operations, two Harney County forage markets are possible

2 Refuge management's attitude changed in regard to livestock grazing on the Refuge. A concentrated effort was made to reduced livestock numbers on the Refuge over the next eight years. Reductions also were stimulated by a predator control ban on U.S. Fish and Wildlife lands. This ban resulted in a need for more nesting cover. Thus, reduction of grazing was necessary to allow more vegetative cover to establish in ground nesting areas.
Figure 4. Actual Use AUMs from the Malheur National Wildlife Refuge Grazing and Haying Program, 1960-1987.
candidates for market interdependence: 1) The private forage land lease market; and 2) the hay market. Depending upon how a majority of permittees altered their livestock operations in response to Refuge cutbacks, one or both of these private markets could reveal the effects of public/private forage market interdependence.

Three examples of possible permittee responses are: 1) Leasing of private land; 2) buying of hay; 3) development of hayland. For each choice, a reduction forage quantity provided the Refuge is a stimulus to change the actions of private forage markets participants, both permittees and nonpermittees. This stimulus is the source of market interdependence. Under the first two responses, increased demand occurs in the private market and puts upward pressure on forage prices. For the third response, development of additional hayland can result from several, nonexclusive factors: 1) Anticipation of future hay price increases; and 2) permittee desire for his/her operation to be a seasonally balanced operation. In either instance, the Refuge provides the stimulus for a potential hay market supply increase compared with demand, thereby creating possible downward pressures on future hay prices.

To select which of the above permittee responses is most common, a personal interview survey was conducted. The objective of this survey is to determine ranch management adjustments taken by permittees in response to actual quantity reductions of Refuge forage. This survey covers all existing and former permittees who were able and willing to cooperate (Appendix A contains the survey form employed). Though models are formulated to test interdependence
in both private lease and hay markets, survey results suggest which forage market acted as a substitute for Refuge forage.

**Research Methods**

In this section, three models are formulated to explain private forage market price or quantity. Two markets are private grazing land lease and the third is an alfalfa hay market. For each model, the purpose of model estimation is to test for existence of market interdependence between public/private forage markets. The existence of interdependence is established by statistical significance of an explanatory variable on forage quantity supplied from a public market.

The objective of testing is rejection or nonrejection of a null hypothesis that no market interdependence exists. The null hypothesis is rejected by a statistically significant public market quantity variable to explain variation in private forage market price or quantity. Each model operates from a change in ranch resource endowment research approach.

**Model A--State Grazing Land Lease Markets**

A complete examination of interdependence is an investigation of simultaneous determination of demand and supply equilibria in both BLM/FS markets and private grazing land lease markets. A connection then is made between quantity of Federal forage and demand for grazing in the private market. This type of model is complicated by
provision of seasonal grazing supplies by the BLM and FS, and little research has been done on aggregate market demand theory for seasonal grazing. Time and data constraints have prevented such an investigation in Model A.

Instead, a simple model is formulated to relate changes in supply of BLM/FS grazing with price changes observed in private lease markets. The model is presented below:

\[ PPGR = f(\text{supply shifters; demand shifters; PFR}) \] (3.1)

where:

- \( PPGR \) = percentage change in private grazing land lease rates;
- \( PFG \) = percentage change in Federal forage supplied in BLM/FS markets.

Equation (3.1) relates price changes observed in private lease markets to variables which cause shifts in this market's demand or supply functions. Percentage changes are used for two reasons: 1) Available price data for private grazing land lease markets are much more suitable for percentage change measurement than actual values (this argument is covered in the "Data" portion of this chapter); and 2) changes in public forage market quantities are regarded as more important than absolute levels of BLM/FS quantities in altering private lease rates.

Supply shifters investigated are: 1) An indicator of range condition or forage availability on rangelands as influenced by annual weather fluctuations; and 2) leasor price expectations for
lease rates as influenced by changing land values. Changes in amount of available range forage are estimated by range condition fluctuations. These changes are expected to be negatively correlated with private grazing lease price changes. Conversely, land value changes are expected to have a positive influence on price changes. The implication is that higher land values push up average lease rates due to increased lessor expectations of returns from a higher valued asset.

Land value changes as an explanatory variable is the reverse of the usual causal relationship between land values and agricultural returns. The logic used here is based on ranch land values being largely determined by nonbeef production values (Pope, 1985; Martin and Jefferies, 1966). Under this assumption, increasing land values are a causal aspect for expectations and not a result of increasing market lease rates.

In (3.1), demand shifters include PFG and an indicator for profitability of livestock operations. In the presence of market interdependence, the variable PFG is expected to be negatively correlated with private market price changes. The causal flow for PFG is: a) Decreased resource endowments of BLM/FS grazing; b) increased demand for private grazing land leases from permittee ranchers to replace lost public forage; and c) positive price changes.

Leasing rangeland is an input into livestock production. Profitability changes account for shifts in output demand. These changes are positively correlated with lease rate changes. To
estimate profit ability changes, real calf price changes are used. Indexing of nominal calf prices is from a western ranch cost of production index.

In model estimation of (3.1), three equations are formed for the Pacific Northwest states of Idaho, Oregon, and Washington. The functional form of each state equation is assumed to be linear. An assumption of linear relationships among variables is made in this and other models formulated in this thesis because of well established hypothesis testing techniques for regression coefficients in small samples (Judge, et al., 1982).

After each state equation is separately estimated with Ordinary Least Squares (OLS), data for individual state equations then are combined in a block-diagonal form to estimate Model A coefficients using the Seemingly Unrelated Regression (SUR) technique. As formulated by Zellner (1962), a SUR technique allows for possible efficiency improvements in coefficient estimates by jointly considering data from all equations in one equation. In SUR, efficiency improvements are possible which lower variances for coefficient estimates. These improvements are desirable when an objective of model estimation is testing for statistical significance of individual coefficients such as PFG.

As with OLS estimates, SUR regression coefficient estimates are linear and unbiased when models are specified correctly. However, SUR can improve the reliability of coefficient estimation because it accounts for (a) any correlation between error term vectors in each state equation; and (b) information on all explanatory variables in-
eluded in the system rather than only variables in each equation (Judge, et al., 1982, p. 320).

With SUR, contemporaneous correlation of each state equation's error terms is required to improve coefficient estimates. This correlation comes from difficult to quantify variables. These variables are accounted for in (3.1) by the error term of each state equation. Difficult to quantify variables include seasonal grazing supply shortages, common livestock price expectations in the industry, and shifts of ranch ownership to owners more likely to lease grazing land, i.e. owners whose primary income is from outside of agriculture.

In combining state equations, a SUR technique is used rather than an Error Components model (where regression coefficients are treated as random variables) because state equations are not derived from the same underlying "true" model. For such a "true" model, regression coefficients are equal for each state equation. Estimates are different because of a given coefficient probability distribution function. Rather than conforming to one "true" model, each state equation is hypothesized to reflect, in part, localized market structures. These markets are driven by both local feed conditions and national economic forces. In addition, state equations are should have different Federal forage supply influences due to size of BLM/FS grazing programs in each state.
Model B--Harney County Forage Land Lease Market

The purpose of Model B estimation is to test for a statistically significant relationship between quantity of livestock forage provided by the Malheur National Wildlife Refuge and private market forage land lease rates in Harney County, Oregon. This private market is evaluated for interdependence because the Refuge uses private lease rates in Harney County to establish grazing fees. Thus, in a similar vein to the theoretical framework outlined in Chapter II, the appropriateness of using private market data to price Refuge forage is evaluated with Model B estimation.

By using a wildlife refuge case study, however, the research direction of this thesis is changed. The dilemma of interdependent public/private forage markets arises with value appraisal for BLM/FS forage resources with private market data. While the Refuge is a Federal forage market, it is not administered by either agency. Because of this fact, estimation of Models B and C moves this research away from direct applicability to BLM/FS forage valuation. Testing of these models, however, still meets the research objective aimed at investigating the existence of interdependent public/private forage markets.

Research findings in this thesis may be extended, with caution, to market interdependence in BLM/FS forage markets. Similar structure and seasonal forage provision between these Federal grazing programs provide the basis for this extension. Specifically, if ratios of the Refuge grazing program to private forage markets are comparable to ratios of BLM/FS forage and private lease markets, then
existence of market interdependence in Harney County may be implied to occur in BLM/FS grazing markets. Thus, if BLM/FS forage quantities are reduced substantially within one county, evidence of interdependent market influences may be implied from Models B and C results.

To examine interdependence in Model B, a system of equations is created to explain variations in Harney County forage land lease rates. Multiple equations are employed to explain inter-connections between those variables which influence private land market lease rates and other exogenous variables, which indirectly affect this rate. The following equations are formulated:

\[ P = f(C; F; HP) \]  \hspace{2cm} (3.2)

\[ C = f(PF; FB) \]  \hspace{2cm} (3.3)

\[ HP = f(H; C) \]  \hspace{2cm} (3.4)

where:

\( P \) = real private land lease rate per AUM for land classes which provide winter grazing or hay production;

\( C \) = number of cattle (cows and calves) in Harney County;

\( F \) = quantity of forage provided by the Refuge;

\( HP \) = real alfalfa hay prices in Harney County;

\( PF \) = profitability measure for Harney County cattle operations;

\( H \) = quantity of alfalfa hay produced in Harney County;
FB = limiting season of forage production in Harney County.

An inverse demand function is an appropriate form for Equation (3.2) because the leased forage land base is assumed to be predetermined in the short-run (Heiden, 1977). With a fixed quantity of lease land available, demand for leased land is postulated to be positively correlated with real lease rates. Cattle numbers (C) are used to approximate demand because of no available data on lease demand.

The HP variable represents a price of one alternative to leasing, purchase of alfalfa hay. As a substitute for leasing, a positive relationship is expected between variables P and HP.

The last variable in (3.2) represents an interdependence influence stemming from changes in Refuge provision of forage. The total livestock forage provided by the Refuge (F) is postulated to have a statistically significant, negative correlation with P if these markets are interdependent. This negative correlation comes from increased demand for private leases with cutbacks in Refuge forage. Increased demand is part of the adjustment response by permittees who lease forage land to replace Refuge forage reductions.

Demand for leased forage land in Harney County, as represented by C, is not postulated to be an exogenous variable. Rather, Equation (3.3) represents C as a function of Harney County variables for cattle operations profitability and annual fluctuations in a limiting seasonal forage resource. To measure profitability, a normal price concept is used to evaluate profitability of current cattle prices (Lorie, 1947). Normal prices are those which cover all
variable costs given a typical year's sale of cattle products. Positive deviations of current price minus normal price represent incentives to expand. Conversely, negative deviations should correspond with herd reductions.

For a limiting forage resource, spring range is most often the limiting seasonal forage resource for ranches in Harney County (Heintz, 1981). Annual fluctuations of available spring forage are estimated with a range forage yield index developed by the Squaw Butte Experiment Station (Sneva and Britton, 1983).

Finally, Equation (3.4) also is an inverse demand function. This equation is used to explain endogenously determined alfalfa hay price in (3.2). Being a perennial crop, alfalfa hay acreage is assumed to be predetermined in the short-run (Myer and Yanagida, 1984). Quantity of hay produced in Harney County (H) and cattle numbers (C) are explanatory variables for real hay price variation. Use of the variable H assumes that production is equal to consumption in a given year (i.e. no change in stocks). Following standard market theory, HP is expected to vary negatively with quantity of alfalfa hay. Since alfalfa hay is an input for livestock production, the variable C accounts for shifts in output demand (Myer and Yanagida, 1984). A positive coefficient is expected for cattle numbers.

Equations (3.2) through (3.4) are estimated as linear relationships because of hypothesis testing considerations noted earlier in discussion of Model A. These equations form a recursive system if their error terms are uncorrelated. Thus, OLS initially is used #to
estimate these equations. Testing then is done for a diagonal
covariance matrix of OLS error terms from each equation to assess
whether these equations are correctly estimated as a recursive
system.

**Model C--Harney County Alfalfa Hay Market**

In Model C, an investigation is made into another possible
interdependence between private/public forage markets. Purchase of
hay and development of hayland are other ranch management responses
to Refuge forage cutbacks which may influence a private market.
Since most hay sold in Harney County is alfalfa, this hay market is
examined for interdependence by estimation of Model C.

Prior research on alfalfa hay markets includes econometric
modelling by Blake and Clevenger (1984), Myer and Yanagida (1984),
and Konyar and Knapp (1986). These studies are used to help guide
decisions for explanatory variables in equations of the Harney County
alfalfa hay market.

Two influences of Refuge forage reductions are hypothesized for
the Harney County alfalfa hay market: 1) Time lagged increase of
alfalfa hay acreage either by the permittees themselves to replace
lost forage or by other hay producers because of anticipated hay
prices increases; and 2) immediate hay price influence created by
permittee hay purchases to replace reductions in Refuge forage. For
these influences, two equations are formulated to explain how the
Refuge forage program affected acres of alfalfa hay production and
real alfalfa hay prices in Harney County:
HAA = f(Price expectation and Economic Growth Variables; RF; D1) (3.5)

HP = f(H; C; RF) (3.6)

where:

HAA = changes in Harney County alfalfa hay acreage;

D1 = dummy variable for Malheur and Harney lakes flood impact;

RF = absolute change in forage quantity provided by the Refuge;

Variables HP, H, and C are measured the same as in Model B.

Equation (3.5) links changes in Refuge forage to changes in alfalfa hay acreage. Variables in this equation are measured as a change from the previous year's total quantity. However, this equation is not constructed as a first difference equation. Because forage cutbacks in this public market are hypothesized to be replaced by private market forage, variable changes are used to directly tie reductions in quantity of Refuge forage (RF) to increases in private market alfalfa hay acreage (HAA).

Using actual data below as an example, Equation (3.5) links a 24,000 reduction in Refuge AUMs to an 2,400 increase in alfalfa hay acreage.\(^3\) In the relationship of (3.5), variable totals are not

\(^{3}\) Because of differences in measurement periods, this example does show a lagged response of hay production acres in the private market to public market supply. Lags longer than one period also are
postulated to be direct causal factors. Thus, the 1973 quantity of Refuge AUMs, 127,000 does not cause 16,600 acres of alfalfa in Harney County. However, permanent reductions from 127,000 AUMs are postulated to cause increases in Harney county hay acres.

<table>
<thead>
<tr>
<th>Year</th>
<th>Harney County Alfalfa Hay Acres (000)</th>
<th>Refuge Supply (000) AUMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>16.6</td>
<td>127</td>
</tr>
<tr>
<td>1974</td>
<td>19.0</td>
<td>103</td>
</tr>
</tbody>
</table>

Furthermore, the RF variable is postulated to be negatively correlated with HAA only during periods when it is "official" Refuge policy to permanently reduce livestock forage. Here, negative correlation occurs after a 1973 change in Refuge management objectives. Forage quantity changes on the Refuge before 1973 do not influence private market hay acreage. Temporary quantity fluctuations are caused by climate, individual permittee winter forage requirements, and temporary livestock use changes on individual permit fields to meet waterfowl management objectives.

To account for the influence of RF after 1973, estimation of both (3.5) and (3.6) is done with the RF variable in block-diagonal form. This format converts RF into two variables: 1) One variable with annual Refuge quantity changes up to 1973 and then zeroes after-
wards; and 2) the other variable with zeroes to 1973 and Refuge quantity changes starting in 1974.

A block-diagonal format is a structural change approach to estimation of an impact from RF (Johnston, 1984; p. 207). Use of structural change in the RF variable allows for testing of the no market interdependence null hypothesis at two levels. The first level is testing for a statistically significant, negative coefficient for RF starting in 1974. Rejection of the null hypothesis (coefficient of RF equal to zero) provides evidence for market interdependence.

The second level of testing uses a F-statistic from linear restrictions on coefficients to test for structural change (Johnston, 1984, p.207). This F-statistic uses a null hypothesis that coefficients for RF variables are equal in both time periods. Rejection of this null hypothesis with an F-test implies significant changes in coefficients between periods. Testing with this F-statistic supplements the t-test because existence of interdependence implies a structural change in the RF coefficient before versus after "official" Refuge reduction policy, i.e. after the change in Refuge management objectives.

To explain variation of HAA, an experimental approach to econometric modelling is used to derive an unknown "true" model for Equation (10). As described by Koutsoyiannis (1977), theory and data are involved in final model decisions. Four models are evaluated to
represent unknown price expectations\textsuperscript{4} and economic growth in (3.5): (1) Adaptive price expectations and Oregon Farm Real Estate index changes (RE); (2) changes in naive price expectations (NPE) and RE; (3) a change in Eastern Oregon alfalfa acreages (EOAA) to act as a proxy variable for both influences; and (4) a change in Lake County alfalfa acreage (LAA), also used as a proxy variable for price expectations and economic growth.

Both price expectations and economic growth are hypothesized to be positively correlated with HAA. Expectations of product price long have been regarded as a potential explanation for crop acreage decisions by farmers (Nerlove, 1956). Economic growth is included as a variable to explain increases in HAA caused by rising costs, especially land values. Increases in land value create pressure to transfer irrigated land out of alfalfa production to higher valued crops in areas where other crop alternatives are feasible. This pressure is perceived as a cause of increased development of irrigated alfalfa land in areas like Harney County where climate prevents most other alternative crops from being grown.\textsuperscript{5} The positive influence of economic growth on HAA is approximated by an agricultural real estate price index for Oregon.

\textsuperscript{4} Market interdependence can be evaluated with rational price expectations in the alfalfa hay market. One such method for multivariate forecasting models, according to Miskin (1983), involves Granger causality testing similar to the approach used by Buongiorno, et al. (1985). Problems with Granger causality previously have been mentioned.

\textsuperscript{5} This reasoning for expansion of Harney County alfalfa hay acreages during the 1970s is expressed by a former Harney County Extension Agent Friedrichsen (1988).
Direct measurement of price expectations in Model 1 follows Nerlove (1956). Changes in price expectations are formed adaptively in time period t by:

\[ p_t^* - p_{t-1}^* = b[p_{t-1} - p_{t-1}] \]  

where \( p^* \) and \( p \) are expected and actual prices, respectively. The coefficient of expectation, \( b \), represents a constant adjustment in forecast errors.

Under adaptive expectations, HAA is assumed to be a function of:

\[ HAA_t = f(p_t^* - p_{t-1}^* ; RF_t ; RE_t ; D1) \]  

To solve for both unobserved price expectations in this crop supply response model, (3.7) and (3.8) are combined to form price expectations as a function of HAA, RF, RE, D1, and observed prices. Substitution of these price expectation equations in (3.8) gives:

\[ HAA_{t+1} = f(HAA_t ; p_t^* - p_{t-1}^* ; RF_{t+1} ; RF_t ; RE_{t+1} ; RE_t ; D1) \]  

Equation (3.9) is used to estimate Model 1 coefficients, where the coefficient for \( HAA_{t-1} \) is equal to \((1-b)\) by assumption. Also by assumption, coefficients for \( RF_t \) and \( RE_t \) are equal \((1-b)/b\) times the \( RF_{t+1} \) and \( RE_{t+1} \) coefficients, respectively.

For the naive price expectations in Model 2, the most recent observed price is treated as a price expectation. Changes in naive price expectations (NPE) are measured by subtracting hay price observed before last year's production from that observed before production
this year \((P_{t-1} - P_{t-2})\). The NPE variable is expected to have a positive coefficient.

Proxy variables EOAA and LAA in Models 3 and 4 are used under an assumption of uniform price expectation and economic growth over all counties in Eastern Oregon. Lake County is chosen as a proxy variable in Model 4 because of this county's climatic similarity to Harney County. In addition, Lake County experienced a similar increase in alfalfa hay acres during the 1970s and early 1980s. These proxy variables are expected to be positively correlated with HAA.

Coefficients for price expectations, economic growth, and intercept term are estimated in block diagonal form. This is done to test for possible structural changes in alfalfa hay markets (Myer and Yanagida, 1984). In their research, Myer and Yanagida report a significant dummy variable for 1973-78 in an alfalfa hay price model. They attribute this significance to a structural change in the agricultural sector. Energy price increases and Russian grain trade are cited as causal factors for this structural change. Thus, the year 1973 is used to separate before and after postulated structural change in these variable's coefficients.

A structural change approach to both Refuge and non-Refuge variables in (3.5) accomplishes two of important objectives. First, structural change allows for more observations in coefficient estimation as compared with separate equations estimated for each time period. Second, a block-diagonal format in all variables separates changes in the agricultural economy from Refuge forage
quantity changes in explanation of HAA. Both of these events occurred at the same time during turbulent economic periods between 1973 and the early 1980s.

The last variable in (3.5), D1, explains a dramatic drop in Harney County alfalfa hay acreage in 1983 due to flooding of Harney and Malheur Lakes. This flooding began in 1982. Thus, the D1 variable has a value of one in 1983 to reflect a drop in alfalfa acres from 1982 and a value of zero in all other years.

The experimental approach used to estimate (3.5) raises concerns of pretest estimation of coefficients in the final model (Ziemer, 1984; Wallace, 1977). These concerns arise from the use of sample data to choose a final, "true" model to represent (3.5). Use of sample data comes from repeated experimentation. An example is re-estimation of model coefficients based on F-test results for structural change. As Wallace (1977) showed, experimentation leads to complex probability distributions for OLS estimators. These distributions depend on restrictions and critical values used in pretests. With pretesting, standard errors and other reported measures of statistical reliability for regression coefficients become misleading (Wallace, 1977).

Pretesting considerations are important in this research because the primary test for interdependence is a significant, negative RF coefficient to explain HAA. Since statistical properties of estimators are altered from conventional OLS assumptions given model experimentation, statistical tests must respect these changed properties.
The desired result of model estimation and testing is to enhance Federal policy-making judgments on the importance of public/private forage market interdependence. However, sound judgments must be made without knowledge of "true" models to explain HAA. Since "true" models are never known, a consistent and sound theoretical basis is required in research procedures. To enhance a consistent and sound basis for this research, pretesting considerations are part of the nine components of research methods for Model C outlined below.

To summarize previously detailed methods of Model C and to add pretesting considerations, nine components of research methods for Equation (3.5) are:

1. Estimation results are reported for all models investigated, a pretesting compromise solution suggested by Ziemer (1984).

2. When data are part of final model decision-making, consistent testing at a five percent significance level is used for F and t-statistics. This testing does not account for complex coefficient probability distributions created by pretesting. This complexity is beyond the scope of this research.

3. Coefficients are estimated with block-diagonal matrices. This format accounts for structural changes in all coefficients. Structural changes begin in 1974 for RF and in 1973 for the intercept, price expectations, and economic growth variables.
(4) A t-statistic is used to test for a significant, negative RF coefficient. This test is the first level of testing the null hypothesis of no market interdependence.

(5) Testing is done for violations of OLS assumptions: a) homoskedastic disturbance terms; b) no autocorrelation among disturbance terms; and c) absence of serious multicollinearity among independent variables.

(6) An F-statistic is calculated to test for structural change in RF, the intercept, price expectation, and economic growth variables. Separate and joint tests are done to assess the appropriateness of block-diagonal format for each variable.

(7) Coefficients are re-estimated without block-diagonal format for those variables where F-statistics cannot reject equality of coefficients in both time periods. T-tests are again done to assess significance of RF variables. RF is dummy variable with zeroes up to 1973 and Refuge quantity changes afterwards. This variable reflects market interdependence theory. Refuge forage quantity changes do not influence the hay market until an "official" forage reduction policy has begun.

(8) Model selection criteria based on estimation from available data (Pesaran, 1982; Pesaran, 1974) are used to select which model best represents (3.5).

(9) As a further check for reasonable estimation of (3.5), compatibility between estimated RF coefficients and survey
information is tested. A restriction test is done on RF coefficients from survey information.

In estimation of Equation (3.6), model coefficient and testing procedures from (3.5) are followed. The logic of structural changes in (3.5) also applies with the hay price equation of (3.5). Thus, Refuge quantity changes (RF) along with the other independent variables of hay production (H) and cattle numbers (C) are represented in block-diagonal form.

As done earlier for (3.4), supply of alfalfa hay is assumed to be a predetermined quantity in the short-run for (3.6) (Myer and Yanagida, 1984). Thus, an inverse demand function is appropriate in (3.6) to account for variation in real alfalfa hay prices (Heiden, 1977). Alfalfa hay production (H) and cattle numbers (C), respectively, are postulated to have negative and positive influences on price. Cattle numbers account for changes in final product demanded (Myer and Yanagida, 1984). Unlike Model B, variable C is assumed to be an exogenous variable in this model.

An immediate hay price impact from current RF is expected to be negative. Decreased Refuge market quantity causes an increase in demand for alfalfa hay in private markets. Increased demand then puts upward pressure on real alfalfa hay price (HP).

Based on similar considerations, many of the same research components used above in (3.5) are included in coefficient estimation and testing of (3.6). Exceptions are: 1) Model selection techniques are not required with only one model; and 2) lack of survey
information on price changes from Refuge quantity reductions prevents compatibility testing.

Data

Familiarity with forage markets and ease of data acquisition are major determinants of location choices. Each of these considerations arises from constraints on funding and time. Based on these constraints, Oregon and Pacific Northwest states are used as research locations.

Idaho, Oregon, and Washington

Testing for interdependent markets between BLM/FS and private grazing land lease markets uses state aggregated data in each state. In all of these states, Federal grazing use pattern is similar to that typical of Western public lands--BLM lands provide spring and fall use while FS lands provide summer grazing.

These three states show a range of dependence on Federal livestock forage supplies. Based on 1983 figures (U.S. Department of Agriculture, Economic Research Service, 1983), BLM/FS markets provide about 20 percent of the year-round forage supply in Idaho, 15 percent in Oregon, and less than two percent in Washington. Idaho and Oregon have greater amounts of grazing provided by BLM than FS (Figures 5 and 6). For the limited quantities of Federal forage in Washington, FS provides over three times the amount of BLM forage (Figure 7).
Figure 5. Actual Use AUMs on Federal Lands in Idaho, 1966 to 1985.

* A change in FS computation of livestock grazing use causes increase between 1976 and 1977.
Figure 6. Actual Use AUMs on Federal Lands in Oregon, 1966 to 1985.
* A change in FS computation of livestock grazing use causes increase between 1976 and 1977.
Figure 7. Actual Use AUMs on Federal Lands in Washington, 1966 to 1985.

* A change in FS computation of livestock grazing use causes increase between 1976 and 1977.
In total, livestock grazing use on Federal lands in these three states has remained fairly stable since 1966. In Idaho, BLM grazing use declined slowly until a 1977 drought. After a sharp use reduction due to drought, grazing use has remained stable, but at a lower level than before the drought. BLM grazing use in Oregon has shown only a cyclical pattern since 1966. Permitted use on FS lands has shown declines in Oregon, but increasing grazing use has occurred in Idaho during 1980s. The minor amount of Federal grazing in Washington has been very stable on both BLM and FS lands.

Data used to estimate Equation (3.1) are compiled on an annual basis for each state. Data series run from 1964 to 1986. Constraints on data collection come from: a) private grazing lease surveys which started in 1964; and b) FS grazing use statistics which could only be traced back to 1966. Data sources for each variable are listed in Table 2.

The PFG variable represents actual livestock grazing on both BLM and FS lands. FS grazing statistics are paid authorized use, while BLM grazing is total authorized use on District land and estimated usage on leased lands outside of grazing districts. Both cattle and sheep grazing are included in these livestock usage numbers. One data manipulation is required because the FS changed its calculation of grazing usage between 1976 and 1977 from Animal Month⁶ to a standard AUM measure. The percentage change between these years

---

⁶ An Animal Month (AM) equals one head of cattle over six months of age grazing for one month on FS land. Animals under six months are not counted.
<table>
<thead>
<tr>
<th>Variable Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage change in FS and BLM grazing (PFG)</td>
<td>USDA, FS: <em>Grazing Statistical Summary</em>; USDI, BLM: <em>Public Land Statistics</em> and <em>BLM Facts</em></td>
</tr>
<tr>
<td>Percentage change in private grazing lease rates (PPGR)</td>
<td>Dec. issue of USDA <em>Ag. Prices</em> and before 1980, USDA, ERS <em>Farm Real Estate Market Developments</em></td>
</tr>
<tr>
<td>Percentage change in average annual calf prices for Idaho, Oregon, and Washington (CPL1)</td>
<td>USDA <em>Ag. Prices</em> Annual Summary publication</td>
</tr>
<tr>
<td>Livestock production input cost index</td>
<td>USDA AND USDI, 1986</td>
</tr>
<tr>
<td>Pasture and range condition index (CON)</td>
<td>Idaho Dept. of Ag.; Kriesel (1987)</td>
</tr>
<tr>
<td>Percentage change in hay prices for Washington (HPW)</td>
<td>annual USDA <em>Crop Values</em> publication</td>
</tr>
<tr>
<td>Percentage change in grazing land values for each state (LV)</td>
<td>USDA, ERS <em>Farm Real Estate Market Developments</em>, Aug 1981 and USDA, 1986</td>
</tr>
</tbody>
</table>
represents 1976 animal numbers adjusted by 1977 average grazing use per Animal Unit.

Private grazing lease rates come from an annual spring survey which asks farmers and ranchers to report average lease rates in their area. Nelson and Garratt (1984) report that the results of this survey could be expected to reasonably reflect changes in average values, but do not necessarily represent true average values for private leases in an area. Thus, this data series is used in its most appropriate manner--measuring percentage changes.

A consistent data series for pasture and range feed conditions is available for only Idaho and Oregon. This monthly measure of condition is an index measure ranging in value from 0 to 100. Extreme drought is represented by values under 35 and values over 80 reflect good to excellent range conditions. An August measure is used for the CON variable to represent weather induced supply shifts. Range condition index change is measured as a deviation from the 1964-86 average. For Washington, hay price changes are used as a proxy variable for weather induced range condition changes between years.

The other supply shifter is represented by nominal changes in grazing land values (LV). Discontinued in 1981, index values after this date are based on changes in farm real estate value index for each state. The underlying assumption is that farmland value changes approximate value changes in grazing land.

Lastly, profitability changes are measured by changes in real calf prices (CPL1). Nominal calf prices are adjusted using a livestock cost of production index. Sheep prices are not included
because cattle operations dominate Federal grazing usage and private grazing lease rate measures. Profitability changes are lagged one year to reflect a Fall marketing period for livestock. Thus, this year's profits affect next spring's private grazing lease rates rather than the preceding spring's rates.

**Harney County**

Data sources for the case study portion of this research are shown in Table 3. As before, these are annual data series. Model B's data series is only 16 years long (1972 to 1987) as it is constrained by private grazing lease rate information. Data are available for Model C from 1958 to 1987. Original data used in estimation of Models B and C are contained in Appendix B.

Because data are available only from 1972, estimation of Model B coefficients does not include block-diagonal format to test for structural change as in Model C. Lease rate data are not available to support such estimation procedures. To determine private forage land lease rates, annual agricultural land use value assessments are used. Assessments of agricultural land use values did not begin until 1973 in Oregon.

These value assessments are done by County Assessor's Offices for property tax purposes. Assessed use land value for agriculture is determined by dividing a net income to land (based on rents from typical lease agreements) by a capitalization rate. This "cap rate" is a combination of Federal Land Bank interest rates with county tax
<table>
<thead>
<tr>
<th>Variable</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private land</td>
<td>Harney County Assessor’s Office - Agricultural land value assessment;</td>
</tr>
<tr>
<td>Lease Rates (P)</td>
<td>DePue (1988)</td>
</tr>
<tr>
<td>Actual use AUMs of grazing &amp; haying,</td>
<td>Malheur National Wildlife Refuge; Johnson (1988)</td>
</tr>
<tr>
<td>Malheur National Wildlife Refuge (F,RF)</td>
<td></td>
</tr>
<tr>
<td>County data for cattle (C);</td>
<td>Oregon State University Extension Service, Office of Economic Information</td>
</tr>
<tr>
<td>hay acreage (HAA), price (HP), and production (H)</td>
<td></td>
</tr>
<tr>
<td>Yield Index (FB)</td>
<td>Sneva and Britton (1983) before 1976; calculated after that with data from NOAA, Climatological Data</td>
</tr>
<tr>
<td>Profitability (PF)</td>
<td>Cattle prices and cost index from USDA Agricultural Prices; Harney County ranch costs from Heintz (1981); indexing of ranch cost categories (Kearl, 1982); interest rates --Melichar (1987)</td>
</tr>
<tr>
<td>GNP deflator</td>
<td>Oregon State University Extension Service, Office of Economic Information; Council of Economic Advisors (1988)</td>
</tr>
</tbody>
</table>
rates to determine an interest rate divisor. With information available on assessed value and "cap rates," net returns are estimated as an approximation of private lease rates.

To calculate private forage land lease rates, net returns are averaged from agricultural land production classes III, IV, and V. These production classes represent most of productive, flood irrigated land on the Refuge (Constantino, 1986). Forage production on these land classes ranges from grass hayland producing a maximum of one and one-half tons of forage per acre (Class III) to dryland pasture which yields one-fourth to one-half ton of forage per acre (Class V).

Of the other variables used in Models B and C, most are straightforward and require little further explanation about their calculation. Exceptions are variables for PF and FB.

As mentioned earlier, the PF variable is measured as deviations of current prices from normal beef prices. Current prices are from Oregon beef cattle price series appearing in USDA Agricultural Prices publication. Normal prices are derived from 1980 variable costs. These costs are an average over different sized Harney County cattle operations (Table 4). The livestock input cost categories from 1980 are then indexed between 1970 to 1986 to be comparable to 1980. Following Kearl (1982), indexing is done with USDA input prices paid indices for agriculture. Interest on operating expenses is calculated each year with current operating loan interest rates.

With annual cost of production data, average beef production per cow is then divided into the total variable costs per cow to deter-

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Dollars per Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Hired labor</td>
<td>30.33</td>
</tr>
<tr>
<td>B. Feed purchased</td>
<td>25.84</td>
</tr>
<tr>
<td>C. Rent &amp; grazing fees</td>
<td>26.44</td>
</tr>
<tr>
<td>D. Repairs &amp; trucking transportation</td>
<td>18.81</td>
</tr>
<tr>
<td>E. Utilities</td>
<td>8.39</td>
</tr>
<tr>
<td>F. Vet. Services &amp; Supplies</td>
<td>4.25</td>
</tr>
<tr>
<td>G. Insurance</td>
<td>8.59</td>
</tr>
<tr>
<td>H. Taxes</td>
<td>15.45</td>
</tr>
<tr>
<td>I. Crop expenses - seed, chemical, fertilizer</td>
<td>7.97</td>
</tr>
<tr>
<td>J. Fuel, oil, grease</td>
<td>18.09</td>
</tr>
<tr>
<td>K. Fencing &amp; Building</td>
<td>4.78</td>
</tr>
<tr>
<td>L. Animals purchased</td>
<td>23.11</td>
</tr>
<tr>
<td>M. BLM &amp; FS grazing</td>
<td>9.99</td>
</tr>
<tr>
<td>N. Custom hire</td>
<td>10.84</td>
</tr>
<tr>
<td>O. Miscellaneous - legal &amp; marketing</td>
<td>5.00</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>217.88</strong></td>
</tr>
<tr>
<td>Interest on operating expenses</td>
<td>16.66</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>234.55</strong></td>
</tr>
</tbody>
</table>
mine normal price for each year. In Harney County, average annual beef production per cow is 4.35 hundredweight (Heintz, 1981). Current price deviations are adjusted to a real basis with a GNP deflator.

Variable FB measures annual fluctuations in availability of limiting seasonal forage production in Harney County--spring season. To approximate FB, a precipitation-yield relationship is used. This relationship correlates previous September to this year's June precipitation with range forage yields (Sneva and Britton, 1983). The precipitation index comes from moisture measurements at the Burns airport as an estimate of annual moisture totals in Harney County.

Lastly, an example is shown in Table 5 of how variables in both Models B and C are related based on their time period of measurement. This table is included because of the variety of time periods when annual variables are measured. In addition, various lag relationships are outlined for each model.
Table 5. Period of Measurement for Models B and C Variables, an Example Using the Year 1976.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model B - Grazing Land Lease Market</strong></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Throughout 1976 though most leases agreed to in spring</td>
</tr>
<tr>
<td>C</td>
<td>Jan. 1, 1976</td>
</tr>
<tr>
<td>F</td>
<td>Federal fiscal year (FY) 1976, most grazing from fall 1975 to spring 1976</td>
</tr>
<tr>
<td>HP</td>
<td>July 1975 to July 1976</td>
</tr>
<tr>
<td>PF</td>
<td>Fall of 1975 and preceding falls for lags</td>
</tr>
<tr>
<td>FB</td>
<td>Precipitation from Sept. 1974 to June 1975</td>
</tr>
<tr>
<td>H</td>
<td>Growing season during 1975</td>
</tr>
<tr>
<td><strong>Model C - Alfalfa Hay Market</strong></td>
<td></td>
</tr>
<tr>
<td>HAA</td>
<td>1976 hay acres minus 1975 acres</td>
</tr>
<tr>
<td>RF</td>
<td>FY 1976 - FY 1975 Refuge livestock forage quantities</td>
</tr>
<tr>
<td>RE</td>
<td>Percentage change in OR Ag. Real Estate Index from 1973 to 1976</td>
</tr>
<tr>
<td>NPE</td>
<td>1975 minus 1974 HP</td>
</tr>
</tbody>
</table>

C, H, HP are measured like in Model B
CHAPTER IV

RESULTS

In this chapter, estimation results are presented from three econometric models for public/private market interdependence. The first model (A) is for BLM/FS and private grazing lease markets in Idaho, Oregon, and Washington. The second and third models (B and C) are for a case study of the Malheur National Wildlife Refuge grazing program and private forage markets in Harney County, Oregon.

The purpose of model estimation is to test for statistically significant evidence in support of a hypothesis on market interdependence. Primary testing is for significant, negative coefficients on Federal market quantity variables. In Model C, sufficient data are available to allow for an additional, supporting test of interdependent markets--a coefficient structural change for the Federal market quantity variable. Structural change is assumed to occur after initiation of an "official" reduction policy in a public forage market. Unless otherwise noted, all statistical testing in this chapter is done at a five percent level of significance. The null hypothesis in each model is that market interdependence does not exist.

Before presentation of econometric results for Models B and C, findings from a survey of Refuge permittees are presented. The purpose of this survey is to determine actual ranch management adjustments to forage reductions in the Refuge grazing program. Response results then are aggregated to use in coefficient
restriction testing for Model C. Restriction testing is done to check the reasonableness of RF coefficient estimation in econometric models. Compatibility between survey results and econometric estimation is assessed by restriction testing.

Testing for violations of OLS assumptions is done on all econometric models to verify the statistical significance of coefficients for Federal forage quantity variables. Violations (autocorrelation, heteroskedasticity, and multicollinearity) are evaluated using the following techniques: 1) Durbin-Watson (D-W) statistic and exact D-W test for positive autocorrelation (Judge, et al., 1982) along with an amended D-W test for negative autocorrelation (Koutsoyiannis, 1977); 2) regressions of squared residual terms ($e^2$) on independent ($x$) and predicted dependent ($y$) variables and plotting of $e^2$ against $y$ for heteroskedasticity; 3) computations of partial correlation coefficients and regressions of independent variables on one another to judge the extent of multicollinearity. Additional evidence for multicollinearity follows recommendations from Belsley, et al. (1980). They recommend condition indexes computed from eigenvalues in principle components analysis. Depending on differences in scale of data measurement, computation of eigenvalues from independent variables uses either a covariance or correlation matrix.

All econometric computations in this thesis are done with the computer program SHAZAM version 6.0 (White, et al., 1987) using a VAX system hardware with UNIX operating system.
Estimation and Testing of Model A

Plots of percentage change in Federal grazing use versus percentage change in private market grazing lease rates are shown in Figures 8 through 10. These state data show little indication of a negative relationship between Federal forage quantity and private lease price changes. However, two dimensional plotting is not the sole indicator for linear relationships between variables when multivariate relationships are postulated.

Estimated OLS regression results show that none of the estimated equations significantly explained variation in private lease rate changes (Table 6). F-statistics for each state equation do not reject a null hypothesis of zero coefficients for all variables. With variables expressed as percentage changes, grazing land lease rates (PPGR) are regressed against BLM/FS forage quantity changes (PFG), grazing land value changes (LV), range condition changes (CON) or hay price (HPW) acting as a proxy variable in Washington, and one year lagged calf prices indexed by livestock production costs (CPL1).

Plotting results are confirmed by PFG coefficient estimation for Idaho, Oregon, and Washington. Estimated coefficients for Federal forage quantity changes are not supportive of market interdependence. PFG coefficients for Oregon and Idaho are not significantly different from zero. Idaho's PFG coefficient has a t-statistic significantly different from zero at a low level (ten percent), but it is positive. A positive value implies that private market grazing land lease rates decrease when Federal supply declines, a result opposite to market
Figure 8. Plot of Percentage Changes in Idaho, Federal Grazing Supply Compared to Nominal Private Grazing Land Lease Rates.
Figure 9. Plot of Changes in Oregon, Federal Grazing Supply Compared to Nominal Private Grazing Land Lease Rates.
Figure 10. Plot of Percentage Changes in Washington, Federal Grazing Supply Compared to Nominal Private Grazing Land Lease Rates.
Table 6. OLS Estimation of Idaho, Oregon, and Washington State Equations, Dependent Variable of Percentage Change in Private Lease Rates (PPGR).

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ESTIMATED COEFFICIENT</th>
<th>T-STATISTIC 14-DF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IDAHO</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>0.402</td>
<td>0.164</td>
</tr>
<tr>
<td>PFG</td>
<td>0.707</td>
<td>1.783</td>
</tr>
<tr>
<td>LV</td>
<td>0.535</td>
<td>2.631*</td>
</tr>
<tr>
<td>CON</td>
<td>-0.001</td>
<td>-0.008</td>
</tr>
<tr>
<td>CPL1</td>
<td>0.094</td>
<td>1.173</td>
</tr>
<tr>
<td><strong>OREGON</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>2.182</td>
<td>0.561</td>
</tr>
<tr>
<td>PFG</td>
<td>-0.423</td>
<td>-0.332</td>
</tr>
<tr>
<td>LV</td>
<td>0.309</td>
<td>0.827</td>
</tr>
<tr>
<td>CON</td>
<td>0.233</td>
<td>0.921</td>
</tr>
<tr>
<td>CPL1</td>
<td>0.074</td>
<td>0.489</td>
</tr>
<tr>
<td>N = 19</td>
<td>R² = 0.447</td>
<td>ADJUSTED R² = 0.2893</td>
</tr>
<tr>
<td>F₄,₁₄ = 2.834</td>
<td></td>
<td>DURBIN-WATSON = 2.012</td>
</tr>
<tr>
<td><strong>WASHINGTON</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>7.884</td>
<td>1.419</td>
</tr>
<tr>
<td>PFG</td>
<td>2.370</td>
<td>1.696</td>
</tr>
<tr>
<td>LV</td>
<td>-0.032</td>
<td>-0.066</td>
</tr>
<tr>
<td>HPW</td>
<td>0.136</td>
<td>0.844</td>
</tr>
<tr>
<td>CPL1</td>
<td>-0.270</td>
<td>-1.405</td>
</tr>
<tr>
<td>N = 19</td>
<td>R² = 0.321</td>
<td>ADJUSTED R² = 0.127</td>
</tr>
<tr>
<td>F₄,₁₄ = 1.652</td>
<td></td>
<td>DURBIN-WATSON = 2.531</td>
</tr>
</tbody>
</table>

* Significant at the 1 percent level.
interdependence theory. Thus, results from these OLS equations do not support the hypothesis of interdependent Federal/private forage markets.

Violations of OLS are not serious. Little evidence exists for heteroskedasticity and multicollinearity problems. However, some autocorrelation problems are present. For heteroskedasticity, regression tests for $e^2$ do not reject a null hypothesis of $e^2$ being uncorrelated with $x$ and $y$ variables for any state equation. Thus, an assumption of homoskedastic error variances is not rejected in these equations.

Multicollinearity between independent variables also is not regarded as serious in any equation. The low explanatory power of each equation is reflected in the statistical insignificance of most coefficients. Maximum condition indexes for each data set are 5.85 (Idaho), 9.77 (Oregon), and 10.52 (Washington). These index numbers are well under a 20 to 30 level for serious collinearity data problems (Johnston, 1984). Given the percentage change measurement of variables, eigenvalues are computed from covariance matrices.

In other multicollinearity tests, none of the regressions among independent variables show statistically significant relationships among regressors. Also, the largest correlation coefficients are between CPL1 and CON (0.48) for Idaho data and between CON and PFG (0.43) for Oregon data. Neither of these correlations is strikingly high.

The common problem of autocorrelation among time-series data is present in these state models. D-W statistics for Oregon and
Washington equations reject an amended D-W test for no first-degree autocorrelation in favor of negative autocorrelation. However, correction for negative autocorrelation in these equations is not done to improve coefficient variance estimates. Instead, efficiency improvements in coefficient estimation are done with a SUR technique described below.

Estimated results for state equations as reported in Table 6 are inconsistent with market interdependence theory. Experimentation with other equations, however, does not materially change the state equation estimates. Other equations do not support for market interdependence in PFG coefficient estimates. Variations tried in these equations are: 1) Grazing rates evaluated in real terms; 2) range condition variable dropped from equations because of its high correlation with PFG variables and low level of explanatory power for lease rate changes; 3) percentage changes of BLM/FS grazing use evaluated as separate variables.

Given unsatisfactory results from separate equation estimation, a SUR technique is used to improve the efficiency of coefficient estimation. If error terms between models are correlated contemporaneously and independent variable matrices \( (X) \) are different in each equation, estimated regression coefficients should have lower estimated variances with SUR than if each equation is estimated separately with OLS (Judge, et al., 1982).

Since each equation has a different \( X \) matrix, contemporaneous correlation among error terms must be present for possible efficiency improvements. This correlation is shown by a non-diagonal covariance matrix.
matrix of state equation error terms. The error term matrix for the three state equations is significantly different from a diagonal matrix at a five percent level of significance (Table 7). Testing is done with a Breusch-Pagan Lagrange Multiplier Test (Judge, et al., 1982).

The resulting SUR estimation shows a greater statistical significance level for LV and PFG coefficients in Idaho and Washington equations (Table 7). Otherwise, there is not much improvement in significance of coefficients nor in support of market inter-dependence.

To test for significant differences between a negative coefficient for Oregon's PFG coefficient and the other two states' positive PFG coefficients, cross model restrictions are used in SUR estimation. A Wald Chi-square statistic with one degree of freedom (df) is 1.5 Oregon equal to Idaho and 3.4 for Oregon equal to Washington. Neither statistic rejects a hypothesis of no difference between regression coefficients. Thus, sign differences between equations on PFG are not statistically significant.

Finally, testing is done for significant differences between state equations. A joint hypothesis is evaluated for equality of each independent variable's coefficient between the three equations. A likelihood ratio test for unrestricted versus restricted SUR systems' estimates then is used to test this equality hypothesis. This test generates a Chi-square distributed statistic of 3.35 with five degrees of freedom. A null hypothesis of equality among regression coefficients is not rejected.
Table 7. Covariance Matrix of Error Terms and SUR Estimation of Three State Equations where the Dependent Variable is PPGR.

Covariance Matrix of OLS Error Terms

<table>
<thead>
<tr>
<th></th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>46.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E2</td>
<td>53.56</td>
<td>119.86</td>
<td></td>
</tr>
<tr>
<td>E3</td>
<td>-48.1</td>
<td>-5.46</td>
<td>180.5</td>
</tr>
</tbody>
</table>

BREUSCH-PAGAN LAGRANGE MULTIPLIER STATISTIC = 11.276

CHI-SQUARE WITH 3 DF

<table>
<thead>
<tr>
<th>MODEL</th>
<th>VARIABLE</th>
<th>ESTIMATED COEFFICIENT</th>
<th>T-STATISTIC 14 DF</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>2.123</td>
<td>1.082</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV</td>
<td>0.321</td>
<td>2.348</td>
<td>0.385</td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>-0.096</td>
<td>-0.878</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IDAHO</td>
<td>3.832</td>
<td>1.191</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFG</td>
<td>-0.566</td>
<td>-0.694</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OREGON</td>
<td>0.093</td>
<td>0.332</td>
<td>0.091</td>
<td></td>
</tr>
<tr>
<td>LV</td>
<td>0.102</td>
<td>0.841</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>0.134</td>
<td>0.760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>5.996</td>
<td>1.366</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFG</td>
<td>1.769</td>
<td>1.843</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WASH-INGTON</td>
<td>0.144</td>
<td>0.402</td>
<td>0.303</td>
<td></td>
</tr>
<tr>
<td>LV</td>
<td>-0.268</td>
<td>-1.696</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPL1</td>
<td>0.153</td>
<td>1.325</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Given the poor fit in Oregon and Washington equations, an inability to reject state equation differences is not surprising. Restricted coefficient results resemble coefficients from Idaho's equation:

<table>
<thead>
<tr>
<th>Variable</th>
<th>SUR Coefficients with Equality Restrictions</th>
<th>SUR Coefficients Idaho Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.7022</td>
<td>2.123</td>
</tr>
<tr>
<td>PFG</td>
<td>0.463</td>
<td>0.477</td>
</tr>
<tr>
<td>LV</td>
<td>0.342</td>
<td>0.321</td>
</tr>
<tr>
<td>CPL1</td>
<td>0.0423</td>
<td>0.084</td>
</tr>
<tr>
<td>CON</td>
<td>0.0574</td>
<td>-0.096</td>
</tr>
</tbody>
</table>

Even with efficiency improvements in coefficient estimation, final results are not supportive of the market interdependence hypothesis. A significant, positive coefficient for PFG in Idaho's equation implies that reductions in Federal grazing supplies lead to reductions in private grazing land lease rates. This result is the opposite to that expected under the market interdependence hypothesis. PFG coefficients in the other state equations are not statistically different from zero.

Rejection of the market interdependence hypothesis can result from either or both joint hypothesis components of Model A--theory and model functional form. The main problem with Model A, however, is perceived to be a lack of data variation in BLM/FS forage quantity changes (PFG) due to state data aggregation. As mentioned earlier, BLM/FS have not had "official" policies of livestock forage reductions over statewide areas. To correct for this deficiency in model estimation, Models B and C are formulated with data from an
area where "official" public market policy was to reduce forage quantities.

**Survey of Malheur Refuge Permittees**

The purpose of this survey is to determine actual ranch management responses to a policy of forage quantity reductions in a Federal market. Response information is aggregated and used to judge which private forage markets act as substitutes for Refuge forage. Survey data also is used as a check of econometric estimation. Compatibility of survey results and coefficient estimates is assessed by restriction testing of Refuge variables in Equation (3.5) of Model C.

In this survey, good coverage is obtained for present Refuge permittees. However, due to difficulties in tracking them down, past permittees are not as well represented. Based on 1972 Refuge records, this survey accounts for 50 percent of permits over 100 AUMs (31 out of 62) and approximately 50 percent of total permitted use (125,000 AUMs) that year. Thus, the survey covers adjustments by about half of those operations using Refuge forage during its peak period.

Corresponding with market interdependence theory, changes in ranch management practices are linked to Refuge grazing program changes made from 1973 to 1981. Refuge permit changes included reductions in permitted livestock grazing use, changing season of use, and permit cancellation (with a transfer of ranch ownership). In addition to these identified permit changes, ranch management adjustments include responses to uncertainty created by numerous Refuge grazing program changes.
According to survey respondents, Refuge grazing program changes are the primary, but not the sole reason for changing ranch management practices. Ranch management responses are categorized into ten different reactions. These responses are ranked according to the percentage of total surveyed operators who responded with each adjustment (Table 8). This wide variety of responses reflects, in part, a diversity of resources available to livestock operations in Eastern Oregon.

Common management responses to permit changes are improvement of deeded land (32 percent), buying hay (26 percent), buying land (19 percent), and reduction of herd size (19 percent)—either temporarily or permanently (Table 8). Leasing of additional land (13 percent) and altering livestock selling pattern (13 percent) are among a second tier of responses. These figures mean, for instance, that improvements on deeded land have been done by 32 percent of all operators surveyed, or about one-third of the total.

Since more than one response is the norm, these percentages do not add up to 100 percent. For example, a reduction in permitted AUMs might cause an operator to buy more hay (Response B) and to change from selling yearlings to weaners (Response F) to save hay already produced.

Of the 31 operators surveyed, six permittees said their permits did not change enough to alter their operations. For those 25 ranches where permit changes did alter management of their operations, permit changes include reduction in AUMs on 14 permits, cancellation of nine permits, and uncertainty due to permit size
Table 8. Ranch Management Responses to Changes in Refuge Grazing Permits, Survey Results of Permittees on the Malheur National Wildlife Refuge.

<table>
<thead>
<tr>
<th>RESPONSE</th>
<th>PERCENTAGE OF TOTAL SURVEYED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Improvements on deeded land</td>
<td>32</td>
</tr>
<tr>
<td>B) Buy hay</td>
<td>26</td>
</tr>
<tr>
<td>C) Reduce herd size or sell out completely</td>
<td>19</td>
</tr>
<tr>
<td>D) Buy land (included buying into grazing associations)</td>
<td>19</td>
</tr>
<tr>
<td>E) Lease additional land</td>
<td>13</td>
</tr>
<tr>
<td>F) Change livestock selling pattern (example: cull open cows in fall rather than them carry through winter)</td>
<td>13</td>
</tr>
<tr>
<td>G) Change seasonal use pattern of existing operation's resources (example: converting irrigated pasture to rake-bunch grazing for winter use)</td>
<td>10</td>
</tr>
<tr>
<td>H) Draw down hay stocks - store less hay</td>
<td>10</td>
</tr>
<tr>
<td>I) Sell ranch</td>
<td>7</td>
</tr>
<tr>
<td>J) Emergency forage program replaced loss of forage from Refuge permit change</td>
<td>3</td>
</tr>
<tr>
<td>K) None - permit did not change enough to warrant operation change</td>
<td>19</td>
</tr>
</tbody>
</table>

Total Survey Respondents: 31
fluctuations in two others. A total forage reduction of about 48 percent was experienced by these 25 operators. Out of 52,000 AUMs used by surveyed permittees in 1972, roughly 25,000 AUMs were cut back during the period of Refuge livestock grazing reductions.

Most responses to Refuge permit changes are to alter management of their existing resources (Responses A, C, F, G, or H). The most common ranch management response, deeded land improvements, consists primarily of expansion of existing hayland (via sprinkler irrigation systems) or seeding of crested wheatgrass on rangeland. Of the roughly 4,300 acres improved or developed by surveyed operators, about one-fourth (over 1,000 acres) are developed alfalfa hay acres. Development of these alfalfa hay acres occurs mainly within a couple of years of permit cutbacks.

Buying of hay is the primary response when ranch operators looked outside of their existing resource base to respond to permit changes. Hay buyers in the sample have responded to permit changes by purchasing an additional 2,400 tons of hay annually. Of eight operators who bought hay, six continue to buy hay (four regularly and two when needed) since changes in their Refuge permit. The other two bought hay for a few years until they developed/bought hayland.

In total, the survey results reveal that 13 out of 25 ranch operators who responded to permit changes did so with hay to replace some or all lost Refuge forage. For the alfalfa hay market, survey response totals are over 1,000 acres developed and additional purchases of about 1,650 tons annually. The alfalfa hay purchase
figure includes irregular buyers, but it excludes those who first bought hay and then developed hayland to avoid double counting.

To use survey information in coefficient restriction tests, bought hay is converted to acres using 1974-79 average alfalfa hay yields in Harney County (2.76 tons per acre). Based on a 25,000 AUM reduction over all survey participants, an additional 1,600 acres of alfalfa hay is developed based on survey information. Using this information, Refuge forage variable in Equation (3.5) is tested for compatibility with survey data. A restriction of -0.064 is used in testing, i.e. 64 acres of alfalfa hayland developed per 1,000 AUMs of Refuge forage reduction.

Another response of interest for market interdependence is easing of private rangeland. Only four operators have leased private grazing land as a response to Refuge permit changes. Most leasing was for yearlings on pasture. About 1,500 head were put on leased pasture in surveyed operations. Survey results show that leasing of land is not as common a response as has been envisioned. Some surveyed ranch operators perceive private pasture leasing to be unavailable and/or unaffordable.

One final impression of the effect on permittee livestock operations from Refuge permit changes is that many operators have bought hay or reduced their cow herds during 1987 and 1988. Dry conditions which led to these ranch management decisions cannot be linked directly to changes in the Refuge grazing program or to recent flooding of Malheur and Harney Lakes. Survey results, however,
suggest that a few of the long-term impacts from Refuge permit changes may show up during dry periods like in 1988.

Refuge permit changes have altered many operations. These operations now tend to store less hay or have adjusted ranch forage resources to maintain herd size during normal years. These adjustments mean that further adjustments may be impossible when a dry period does come along. There is no "hay insurance" or excess forage resources available within these operations. A year's supply of hay is typically stored in this area as protection from climatic risks. Thus, during recent drought periods, ranch managers have had to go to hay markets or liquidate part of their herd to insure an adequate feed supply for their remaining livestock.

**Estimation and Testing of Model B**

The purpose of econometric estimation is to test for interdependence between the Malheur National Wildlife Refuge grazing program and the private forage land lease market in Harney County, Oregon. Before estimation, plotting is done for Refuge provided forage (F) and real private market lease rates in Harney County (P) (Figure 11). With exceptions of high lease rates in 1980-82 and in 1987, P has been stable to declining during reductions in Refuge forage since 1973.

Results of plotting along with survey findings suggest a minor impact on Harney County forage land lease rates from Refuge forage reductions. These indications are confirmed by estimation of coefficients for Equation (3.2) (Table 9). Variations in the
Figure 11. Plot of Refuge Forage Provided and Real Private Forage Land Lease Rates in Harney County.
Table 9. OLS Regression Results for Model B System of Equations, Harney County Forage Land Lease Market.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ESTIMATED COEFFICIENT</th>
<th>T-STATISTIC 12-DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation 7: Dependent Variable - P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.4628</td>
<td>0.55</td>
</tr>
<tr>
<td>C</td>
<td>0.0405</td>
<td>1.85**</td>
</tr>
<tr>
<td>F</td>
<td>0.0003</td>
<td>0.05</td>
</tr>
<tr>
<td>HP</td>
<td>-0.0051</td>
<td>-0.53</td>
</tr>
<tr>
<td>N = 16</td>
<td>R² = 0.242</td>
<td>ADJUSTED R² = 0.052</td>
</tr>
<tr>
<td></td>
<td>F₃,₁₂ = 1.274</td>
<td>DURBIN-WATSON = 1.46</td>
</tr>
<tr>
<td>Equation 8: Dependent Variable - C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>107.24</td>
<td>23.92*</td>
</tr>
<tr>
<td>PF Lag1</td>
<td>-0.539</td>
<td>-4.18*</td>
</tr>
<tr>
<td>PF Lag2</td>
<td>0.485</td>
<td>3.75*</td>
</tr>
<tr>
<td>FB</td>
<td>0.102</td>
<td>2.29**</td>
</tr>
<tr>
<td>N = 16</td>
<td>R² = 0.650</td>
<td>ADJUSTED R² = 0.563</td>
</tr>
<tr>
<td></td>
<td>F₃,₁₂ = 7.438</td>
<td>DURBIN-WATSON = 1.88</td>
</tr>
<tr>
<td>Equation 9: Dependent Variable - HP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>93.22</td>
<td>1.33</td>
</tr>
<tr>
<td>H</td>
<td>-0.738</td>
<td>-2.76**</td>
</tr>
<tr>
<td>C</td>
<td>0.522</td>
<td>0.85</td>
</tr>
<tr>
<td>N = 15</td>
<td>R² = 0.3895</td>
<td>ADJUSTED R² = 0.288</td>
</tr>
<tr>
<td></td>
<td>F₂,₁₂ = 3.828</td>
<td>DURBIN-WATSON = 1.32</td>
</tr>
</tbody>
</table>

* Significance level of 1 percent.
** Significance level of 5 percent.
dependent variable, $P$, are not well explained by independent variables $F$ (Refuge forage), $C$ (cattle numbers), and $HP$ (hay prices). An F-test for all independent variables in (7) does not reject a null hypothesis that regression coefficients are equal to zero. Furthermore, the $F$ coefficient is not significantly different from zero based on t-statistic testing.

Results for (3.2) are not supportive of the market interdependence hypothesis. In light of these results, experimentation is done with different formulations to explain a relationship between lease rates ($P$) and Refuge forage ($F$): a) Inverse relationship--$P$ a function of $1/F$; b) measuring $F$ in absolute changes; c) lagging $F$ two and three years. These changes do not give statistically significant $F$ coefficients nor do they improve equational explanatory power.

Examining Equations (3.3) and (3.4) in Table 9, (3.3) has a statistically significant explanatory power with an $F$-statistics of 7.44. However, the $F$-statistic for (3.4) does not reject a null hypothesis of both coefficients equal to zero. To explain cattle numbers in Equation (3.3), a lagged range forage yield index ($FB$) and two lags of a profitability measure ($PF$) have statistically significant coefficients. Both $PF$ coefficients are significant at a one percent level. In (3.4), hay production ($H$) is a significant explanatory variable of real alfalfa hay prices ($HP$), while the cattle numbers ($C$) coefficient is not significantly different from zero.

In Equation (3.3), the $PF$ variable has a negative coefficient for a one period lag and a positive coefficient for a two period lag.
These coefficients mean that for every one dollar real difference between current prices and normal prices (both measured during the fall), Harney County cattle numbers drop about 500 head by the following January 1 and then increase by 500 head before the next January 1 census. As C represents total cattle numbers, a one period lag is postulated to be related to changes in steer numbers retained for yearlings while the second lag explains expected herd build-up.

In accordance with this postulation, non-cow and cow numbers are regressed on one and two period profitability lags, respectively. A one period lag has a negative coefficient to explain non-cow cattle numbers. A two period lag is positively correlated to cow numbers in Harney County:

\[
\text{non-cow} \# = 53.6 - 0.203 \text{ PF Lag1} \quad \text{Adjusted } R^2 = 0.262, \quad (-2.51)
\]

\[
\text{cow} \# = 63.75 + 0.122 \text{ PF Lag2} \quad \text{Adjusted } R^2 = 0.133. \quad (1.82)
\]

With t-statistics in parenthesis below each estimated coefficient, both lag coefficients represent statistically significant relationships for a one-tail test.

These PF lag coefficients correspond to a pattern of producer cattle price responses hypothesized by Jacobs (1985). In this pattern, producers respond to high cattle prices by expanding calf production and to low prices by producing yearlings. When prices are high (positive deviation between observed and normal prices), greater
numbers of steer calves are sold off instead of kept for yearlings. Thus, the coefficient is negative for lag one. Low prices (negative deviation) then induce a greater retention of calves for yearling production by producers who normally produce calves. After these year one adjustments, the second lag shows the expected expansion/contraction influence on herd size from retention of yearling heifers/culling of cow herd because of profitability considerations.

From available sample data, (3.2) through (3.4) are properly tested as a recursive system of equations. As in Model A, a Breusch-Pagan Lagrange Multiplier Test is applied to test for a diagonal covariance matrix of error terms for (3.2) through (3.4). The chi-square statistic generated, 0.9261 with 3 degrees of freedom, can not reject a null hypothesis of a diagonal matrix. Since off-diagonal matrix elements are not different from zero, error terms for these equations are uncorrelated.

In testing for OLS assumption violations, collinearity between independent variables in Model B data sets is not a serious problem. Partial correlation coefficients are moderately high between F and HP (0.49) and PF Lag1 and PF Lag2 (0.64). Both of these correlations are statistically significant in OLS regression. However, eigenvalue condition indexes on independent variables of (3.2) and (3.3) are not high at 4.1 and 3.8, respectively. Eigenvalues are computed with covariance matrices.

Collinearity in (3.2) is not interpreted as a problem. Low explanatory power of this equation, not multicollinearity, is regarded as the main problem. For (3.3), all variables have
significant coefficients with logical signs so that collinearity influences do not change estimation results.

In testing for first-degree autocorrelation, positive correlation between error terms is present in (3.2) and (3.4). An assumption of zero autocorrelation is rejected for both equations with exact D-W tests. A null hypothesis of no autocorrelation is not rejected in (3.3). Positive autocorrelation in (3.4) is attributed to omitted variables (specifically a Refuge forage variable). Since a similar equation is formulated in Model C, no corrective action is taken here. Corrective measures for first-order positive autocorrelation also are not applied in (3.2) because of data considerations outlined below.

Plots of error terms show evidence of heteroskedasticity in (3.2) (Figure 12). Figure 12 results are confirmed by rejection of homoskedastic null hypotheses. All tests of $e^2$ regressed on $X$ independent variables ($X^2_3 = 9.27$) and predicted $y$ ($X^2_1 = 5.4$) and predicted $y^2$ ($X^2_1 = 5.4$) have statistically significant chi-square statistics. Data from (3.3) and (3.4) show no problem with heteroskedasticity in either plotting or regression tests.

Autocorrelation and heteroskedastic error term violations of OLS assumptions are not corrected with generalized least squares in estimation of (3.2). The reasons include: (1) Survey results do not lend support to a relationship between Refuge forage reductions and private forage land lease rates as leasing was not a common management response of permittees; (2) plotting of data between Refuge forage and private lease rates does not show a relationship between
Figure 12. Plot of OLS Error Terms Squared and Real Private Forage Land Lease Rates in Harney County.
these two variables; (3) forage land lease rate data is judged not to be of sufficient quality to pursue further data manipulation. Reasons one and two are self-explanatory. The third reason is expanded upon further in Chapter V.

The result of econometric estimation in Model B is that livestock forage reductions on the Malheur National Wildlife Refuge have no discernible impact on private forage land lease rates in Harney County. The Refuge forage variable coefficient is not statistically different from zero when explaining variations in lease rates. Thus, no support for interdependent public/private forage markets is found in Model B system of equations.

**Estimation and Testing of Model C**

Two influences of Refuge forage reductions are postulated for the Harney County alfalfa hay market: 1) A lagged production response in alfalfa hay acreage; and 2) an immediate price influence created by increased demand for hay. Each influence is evaluated by OLS estimated regression equations.

Hay market data are available before and after initiation of an "official" Refuge management policy to reduce livestock grazing. This data availability allows for estimation of coefficient structural changes. Possible structural changes in the local hay market are induced by a Refuge forage reduction policy and by changing economic conditions in the 1970s (Myer and Yanagida, 1984). To account for both types of structural change, all independent variables are in block-diagonal format.
The primary test for market interdependence is a statistically negative coefficient for a change in Refuge forage (RF). With a negative coefficient, reductions in Refuge forage significantly increase acres of alfalfa hay in Harney County (HAA) and increase real alfalfa hay price (HP). RF coefficients are negative starting in 1974, after Refuge forage reductions had begun.

To supplement regression coefficient t-tests as evidence for interdependence, structural change testing is done on RF coefficients. To assess structural changes, F-statistics are generated from restrictions on coefficients (Johnston, 1984). A significant F-statistic supports interdependence by showing that RF coefficients are different before versus after Refuge forage reductions.

As a last test for evidence of market interdependence, restriction testing with survey information is done on RF coefficients in Equation (3.5). This test is for compatibility of RF coefficients estimation with information from a survey of Refuge permittees.

**Alfalfa Hay Production Influence**

Changes in Refuge forage (RF) show a negative, linear relationship with changes in Harney County alfalfa hay acreage (HAA) (Figure 13). This relationship occurs between 1974-87 but not during 1960-73. These dates correspond to before and after a Refuge policy of forage reduction. To assess RF's influence on HAA in a multivariate setting, four econometric models of Equation (3.5) are formulated (Tables 10 through 13). The block-diagonal format gives two
Table 10. Block-Diagonal Estimation of Model 1 Coefficients to Explain Changes in Harney County Alfalfa Hay Acreages with a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Perioda</th>
<th>Intercept</th>
<th>HAA$_{t-1}$</th>
<th>RE</th>
<th>RE$_{t-1}$</th>
<th>NPE</th>
<th>RF</th>
<th>RF$_{t-1}$</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-73</td>
<td>0.686</td>
<td>0.332</td>
<td>0.026</td>
<td>-0.044</td>
<td>-0.026</td>
<td>0.0202</td>
<td>0.0775</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.84)</td>
<td>(0.91)</td>
<td>(1.03)</td>
<td>(-1.77)</td>
<td>(-1.47)</td>
<td>(0.49)</td>
<td>(1.97)</td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.278</td>
<td>0.0012</td>
<td>-0.052</td>
<td>0.049</td>
<td>0.034</td>
<td>-0.0771</td>
<td>-0.093</td>
<td>-7.25</td>
</tr>
<tr>
<td></td>
<td>(0.48)</td>
<td>(0.006)</td>
<td>(-0.90)</td>
<td>(0.83)</td>
<td>(1.62)</td>
<td>(-1.71)</td>
<td>(-2.23)**</td>
<td>(-4.75)*</td>
</tr>
</tbody>
</table>

N = 27        \quad R^2 = 0.763 \quad \text{ADJUSTED } R^2 = 0.4864 \quad \text{DURBIN'S } H = ^c

* T-statistic with 12 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

** T-statistic with 12 df significant at a 5 percent level, same testing as at 1 percent.

a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.

b Limitations of hay price data restrict observations to begin in 1961.

c With lagged HAA variance greater than one, Durbin's H could not be computed. Using an asymptotically equivalent test suggested by Durbin (Judge, et al., 1985, p.326), regression of e in time t on lagged e and HAA, first degree autocorrelation is rejected for this equation.
Table 11. Block-Diagonal Estimation of Model 2 Coefficients to Explain Changes in Harney County Alfalfa Hay Acreage with a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Intercept</th>
<th>NPE</th>
<th>RE</th>
<th>RF</th>
<th>D1</th>
<th>R^2</th>
<th>Adjusted R^2</th>
<th>N</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-73b</td>
<td>0.321</td>
<td>-0.007</td>
<td>0.004</td>
<td>-0.0016 &amp; -</td>
<td>(0.38)</td>
<td>(-0.43)</td>
<td>(0.19)</td>
<td>(0.14)</td>
<td>0.531</td>
</tr>
<tr>
<td>1974-87</td>
<td>0.787</td>
<td>0.007</td>
<td>0.007</td>
<td>-0.054 &amp; -5.73</td>
<td>(1.71)</td>
<td>(0.41)</td>
<td>(0.39)</td>
<td>(-1.11)</td>
<td>(-4.00)*</td>
</tr>
</tbody>
</table>

* T-statistic with 18 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.

b Limitations on hay price data restrict observations to begin in 1961.
Table 12. Block-Diagonal Estimation of Model 3 Coefficients to Explain Changes in Harney County Alfalfa Hay Acreage with a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Intercept</th>
<th>EOAA</th>
<th>RF</th>
<th>D1</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>N</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-73</td>
<td>0.086</td>
<td>0.044</td>
<td>0.0047</td>
<td></td>
<td>-</td>
<td>0.580</td>
<td>0.460</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>(0.20)</td>
<td>(1.02)</td>
<td>(0.17)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.953</td>
<td>0.041</td>
<td>-0.050</td>
<td>6.64</td>
<td>-6.64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.43)**</td>
<td>(1.49)</td>
<td>(-1.29)</td>
<td>(-4.82)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 21 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

** T-statistic with 21 df significant at a 5 percent level, same testing as at 1 percent.

a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.
Table 13. Block-Diagonal Estimation of Model 4 Coefficients to Explain Changes in Harney County Alfalfa Hay Acreage with a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Perioda</th>
<th>Intercept</th>
<th>LAA</th>
<th>RF</th>
<th>D1</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>N</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-73</td>
<td>0.127</td>
<td>0.307</td>
<td>-0.0017</td>
<td>-</td>
<td>0.586</td>
<td>0.468</td>
<td>28</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td>(0.33)</td>
<td>(1.37)</td>
<td>(-0.06)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.839</td>
<td>0.087</td>
<td>-0.047</td>
<td>-6.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.22)**</td>
<td>(1.29)</td>
<td>(-1.17)</td>
<td>(-4.86)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 21 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated—otherwise two-tail test.

** T-statistic with 21 df significant at a 5 percent level, same testing as at 1 percent.

a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.
Figure 13. Plots of Changes in Refuge Provided Forage (RF) and Changes in Harney County Alfalfa Hay Acreage (HAA), 1960-73 (A) and 1974-87 (B).
coefficient estimates for each variable, one before structural change and the other after any change.

While RF coefficients after 1974 are negative in each model, no RF coefficient is statistically significant. Only $RF_{t-1}$ in Model 1 has a statistically significant, negative coefficient. With a t-statistic of -2.23, this coefficient is significant at a five percent level for a two tail test ($t_{12,.05} = 2.179$).

A significant $RF_{t-1}$ coefficient in Model 1, however, presents the possibility of model misspecification. This misspecification is an exclusion of a lagged RF variable in models formulated to explain HAA. Under adaptive expectations assumptions, the $RF_{t-1}$ coefficient is equal to $[(1-b)/b]*RF$.coefficient. Given that $(1-b)$ is equal to the HAA$_{t-1}$ coefficient and that this coefficient is statistically insignificant from zero, the $RF_{t-1}$ coefficient is expected to be zero rather than significantly negative under adaptive price expectations. From coefficient estimation of Model 1, the rationale for a lagged RF variable as part of (3.5) comes from this variable's inclusion in the "true" model as an indication of Refuge forage reductions rather than because of adaptive price expectations.

F-testing for structural change in Models 1 through 4 also supports a misspecification argument. F-statistics in Table 14 are statistically significant for only RF and $RF_{t-1}$ in Model 1 ($F_{2,19} = 7.421$). This result supports a lagged Refuge supply variable in (3.5).
Table 14. F-statistics Computed to Test for Structural Changes in Initial Block-Diagonal Estimations of Models 1 through 4.

<table>
<thead>
<tr>
<th>Model</th>
<th>Refuge Forage Variable</th>
<th>Price and Economic Growth Variables</th>
<th>Intercept Term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Degrees of Freedom)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7.421*</td>
<td>2.92</td>
<td>0.848</td>
</tr>
<tr>
<td></td>
<td>(2,19)</td>
<td>(4,19)</td>
<td>(1,18)</td>
</tr>
<tr>
<td>2</td>
<td>0.465</td>
<td>0.271</td>
<td>1.986</td>
</tr>
<tr>
<td></td>
<td>(1,22)</td>
<td>(2,22)</td>
<td>(1,21)</td>
</tr>
<tr>
<td>3</td>
<td>1.77</td>
<td>0.003</td>
<td>4.351**</td>
</tr>
<tr>
<td></td>
<td>(1,24)</td>
<td>(1,24)</td>
<td>(1,23)</td>
</tr>
<tr>
<td>4</td>
<td>1.046</td>
<td>1.008</td>
<td>2.23</td>
</tr>
<tr>
<td></td>
<td>(1,24)</td>
<td>(1,24)</td>
<td>(1,23)</td>
</tr>
</tbody>
</table>

* Statistically significant at a 1 percent level.

** Statistically significant at a 5 percent level.
The lag structure with one RF variable is a one year lag in Refuge reduction influence on HAA. For example, Refuge forage changes between the 1974-75 and 1975-76 winter season cause an increase in alfalfa hay acres during 1976 compared to 1975. With the addition of \(RF_{lag}^{1}\), a relationship is estimated between changes in hay acres (HAA) and a second year lag in Refuge forage reduction. Following the above example, \(RF_{lag}^{1}\) connects Refuge reductions between 1973-74 and 1974-75 to HAA from 1975 to 1976.

Three factors are thought be responsible for a further lag in Refuge reduction influence on alfalfa hay acreage. First, most ranch management responses to Refuge permit changes include more than one response. This means that quicker responses such as selling calves instead of yearlings to conserve hay are done initially with alfalfa hay acres developed later. Second, the large capital requirements of alfalfa hay development may cause operators to delay hayland investment for a few years after permit reductions. A third factor to delay implementation of alfalfa hay development is the climatic riskiness of Harney County. A short and highly variable growing season creates difficult growing conditions for alfalfa hay (Gomm, 1979).

Based on evidence from Model 1 and the above third factors, re-estimation of block-diagonal equations for each model includes a lagged RF variable\(^1\) (Tables 15 through 18). Re-estimated RF coefficients are more supportive of market interdependence. Model 2

\(^1\) In Model 1, \(RF_{t-3}^{1}\) is included due to adaptive price expectations. Its coefficient is equal to the \([(1-b)/b]\) times the RF coefficient.
Table 15. Re-Estimation of Block-Diagonal Format for Coefficients in Model 1 with RF\textsubscript{lag} in Model and a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Period\textsuperscript{a}</th>
<th>Intercept</th>
<th>HAA\textsubscript{t-1}</th>
<th>RE</th>
<th>RE\textsubscript{t-1}</th>
<th>NPE</th>
<th>RF</th>
<th>RF\textsubscript{lag}</th>
<th>RF\textsubscript{t-3}</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-73\textsuperscript{b}</td>
<td>1.027</td>
<td>0.263</td>
<td>0.006</td>
<td>-0.040</td>
<td>-0.023</td>
<td>0.046</td>
<td>0.118</td>
<td>0.055</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(1.12)</td>
<td>(0.68)</td>
<td>(0.17)</td>
<td>(-1.54)</td>
<td>(-1.25)</td>
<td>(0.91)</td>
<td>(2.08)</td>
<td>(1.03)</td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.329</td>
<td>-0.009</td>
<td>-0.048</td>
<td>0.047</td>
<td>0.032</td>
<td>-0.0751</td>
<td>-0.089</td>
<td>0.004</td>
<td>-7.18</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(-0.04)</td>
<td>(-0.65)</td>
<td>(0.65)</td>
<td>(1.29)</td>
<td>(-1.60)</td>
<td>(-1.74)</td>
<td>(0.09)</td>
<td>(-4.13)*</td>
</tr>
</tbody>
</table>

N = 27  \hspace{1em} R^2 = 0.786  \hspace{1em} ADJUSTED R^2 = 0.4429  \hspace{1em} DURBIN'S H = \textsuperscript{c}

\textsuperscript{*} T-statistic with 10 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

\textsuperscript{**} T-statistic with 10 df significant at a 5 percent level, same testing as at 1 percent.

\textsuperscript{a} These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.

\textsuperscript{b} Limitations of hay price data restrict observations to begin in 1961.

\textsuperscript{c} With lagged HAA variance greater than one, Durbin's H could not be computed. Using an asymptotically equivalent test suggested by Durbin (Judge, et. al., 1985, p.326), regression of e in time t on lagged e and HAA, first degree autocorrelation is not rejected for this equation.
Table 16. Re-Estimation of Block-Diagonal Format for Coefficients in Model 2 with RF_\text{lag} in Model and a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Perioda</th>
<th>Intercept</th>
<th>NPE</th>
<th>RE</th>
<th>RF</th>
<th>RF_{lag}</th>
<th>D1</th>
<th>R^2</th>
<th>Adjusted R^2</th>
<th>N</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-73^b</td>
<td>0.343</td>
<td>-0.013</td>
<td>-0.0001</td>
<td>0.0402</td>
<td>0.052</td>
<td>-</td>
<td>0.679</td>
<td>0.478</td>
<td>27</td>
<td>2.09</td>
</tr>
<tr>
<td></td>
<td>(0.47)</td>
<td>(-0.88)</td>
<td>(-0.006)</td>
<td>(1.03)</td>
<td>(1.41)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.531</td>
<td>0.031</td>
<td>-0.011</td>
<td>-0.080</td>
<td>-0.095</td>
<td>-6.66</td>
<td>(-1.79)**</td>
<td>(-2.28)**</td>
<td>(-5.04)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.26)</td>
<td>(1.67)</td>
<td>(-0.62)</td>
<td>(-1.79)**</td>
<td>(-2.28)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 16 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

** T-statistic with 16 df significant at a 5 percent level, same testing as at 1 percent.

a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.

b Limitations on hay price data restrict observations to begin in 1961.
Table 17. Re-Estimation of Block-Diagonal Format for Coefficients in Model 3 with RF_{lag} in Model and a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Period^a</th>
<th>Intercept</th>
<th>EOAA</th>
<th>RF</th>
<th>RF_{lag}</th>
<th>D1</th>
<th>R^2</th>
<th>Adjusted R^2</th>
<th>N</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-73</td>
<td>-0.036</td>
<td>0.044</td>
<td>0.027</td>
<td>0.0418</td>
<td>-</td>
<td>0.656</td>
<td>0.512</td>
<td>28</td>
<td>1.91</td>
</tr>
<tr>
<td></td>
<td>(-0.08)</td>
<td>(1.08)</td>
<td>(0.86)</td>
<td>(1.25)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.675</td>
<td>0.034</td>
<td>-0.060</td>
<td>-0.050</td>
<td>-6.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.62)</td>
<td>(1.28)</td>
<td>(-1.61)</td>
<td>(-1.60)</td>
<td>(-5.13)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 19 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated—otherwise two-tail test.

^a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.
Table 18. Re-Estimation of Block-Diagonal Format for Coefficients in Model 4 with RF_{lag} in Model and a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Intercept</th>
<th>LAA</th>
<th>RF</th>
<th>RF_{lag}</th>
<th>D1</th>
<th>R^2</th>
<th>Adjusted R^2</th>
<th>N</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-73</td>
<td>-0.034</td>
<td>0.333</td>
<td>0.025</td>
<td>0.048</td>
<td></td>
<td>0.675</td>
<td>0.537</td>
<td>28</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>(-0.09)</td>
<td>(1.59)</td>
<td>(0.82)</td>
<td>(1.47)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-87</td>
<td>0.577</td>
<td>0.076</td>
<td>-0.056</td>
<td>-0.051</td>
<td>-6.41</td>
<td>(-5.35)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.48)</td>
<td>(1.21)</td>
<td>(-1.49)</td>
<td>(-1.71)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 19 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

a These time periods correspond to pre- and post-Refuge management changes. Other structural changes for intercept and price expectation plus economic growth variables are assumed to start in 1973.
RF coefficients are statistically less than zero after 1974 for a one-tail test \( t_{16,.05} = 1.746 \). While negative, RF coefficients in the other three models are not statistically different from zero.

Insignificant t-statistics for RF coefficients probably stem from collinearity problems in block-diagonal data, specifically between intercept terms and other independent variables. As initial evidence for this postulation, adjusted \( R^2 \) values for these models range from 0.443 (Model 1) to 0.537 (Model 4), yet, except for D1, only one model has other coefficients with statistically significant t-statistics (Model 2). This moderate level of explanatory power with so few statistically significant coefficients is evidence of collinearity problems (Johnston, 1984).

From the data, maximum eigenvalue condition indices for Models 1 through 4 are extremely high (in a range \( 10^9 \) to \( 10^{10} \)) when intercept terms are included in correlation matrices. However, without intercept terms, maximum indices are much lower (from 13.82 for Model 1 to 1.95 for Model 3), under a 20-30 problem range. Thus, collinearity among variables is a problem when intercept terms are in block-diagonal format.

Structural change for intercept terms, price expectations, and economic growth variables are not statistically significant (Table 19). Neither of these alfalfa hay market structural changes occurred in explanation of HAA. Agricultural economy changes did not structurally change coefficients in (3.5). Thus, intercept terms for each model as well as price expectations and economic growth coefficients are not different before versus after 1973.
Table 19. F-statistics Computed to Test for Structural Changes in Block-Diagonal Estimation of Models 1 through 4, Lagged Refuge Variable Included in Estimation.

<table>
<thead>
<tr>
<th>Model</th>
<th>Refuge Forage Variables</th>
<th>Price and Economic Growth Variables</th>
<th>Intercept Term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-statistics</td>
<td>(Degrees of Freedom)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7.304*</td>
<td>2.326</td>
<td>1.046</td>
</tr>
<tr>
<td></td>
<td>(2,18)</td>
<td>(5,18)</td>
<td>(1,18)</td>
</tr>
<tr>
<td>2</td>
<td>5.198*</td>
<td>2.272</td>
<td>0.945</td>
</tr>
<tr>
<td></td>
<td>(2,21)</td>
<td>(2,21)</td>
<td>(1,20)</td>
</tr>
<tr>
<td>3</td>
<td>3.277**</td>
<td>0.050</td>
<td>2.773</td>
</tr>
<tr>
<td></td>
<td>(2,23)</td>
<td>(1,23)</td>
<td>(1,22)</td>
</tr>
<tr>
<td>4</td>
<td>3.626**</td>
<td>1.667</td>
<td>1.344</td>
</tr>
<tr>
<td></td>
<td>(2,23)</td>
<td>(1,23)</td>
<td>(1,22)</td>
</tr>
</tbody>
</table>

* Statistically significant at a 1 percent level.

** Statistically significant at a 5 percent level.
In contrast, F-statistics for structural change in RF and $RF_{lag}$ are highly supportive of market interdependence existence. All four models have a statistically significant structural change in RF coefficients (Table 19). These results mean that RF and $RF_{lag}$ coefficients are significantly different after Refuge forage reductions were begun compared with before Refuge reduction policy.

When coefficients in Equation (3.5) are re-estimated based on structural change results, support for market interdependence is strong (Tables 20 and 21). In these equations, RF and $RF_{lag}$ coefficients are estimated with zeroes to 1973 and Refuge forage change numbers beginning in 1974 (when the RF coefficient is postulated to be negative). The RF variables before Refuge reductions are dropped from estimation due to an expectation of zero coefficients. Coefficient estimation in block-diagonal format (Tables 15 to 18) provides little evidence for non-zero RF coefficients from 1960-73.

The results from Tables 20 and 21 are that all four models have negative, statistically significant coefficients. One-tail t-tests are used to assess significance of RF and $RF_{lag}$ coefficients ($t_{18,.05} = 1.734$ for Model 1; $t_{21,.05} = 1.721$ for Model 1; $t_{23,.05} = 1.714$ for Models 3 and 4). In Models 1 through 3, RF coefficients are significantly different from zero at a 2.5 percent level. Thus, all four models show both levels of support for market interdependence between the alfalfa hay market and the Refuge grazing program. Each model has a statistically negative RF coefficients,
Table 20. Re-Estimation of Models 1 and 2 Based on Testing Results for Coefficient Structural Change with a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Model</th>
<th>Intercept</th>
<th>HAA$_{t-1}$</th>
<th>RE</th>
<th>RE$_{t-1}$</th>
<th>NPE</th>
<th>RF</th>
<th>RF$_{lag}$</th>
<th>RF$_{t-3}$</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.587</td>
<td>-0.040</td>
<td>-0.001</td>
<td>-0.004</td>
<td>0.004</td>
<td>-0.088</td>
<td>-0.064</td>
<td>0.011</td>
<td>-6.07</td>
</tr>
<tr>
<td></td>
<td>(1.47)</td>
<td>(-0.24)</td>
<td>(-0.07)</td>
<td>(-0.24)</td>
<td>(0.27)</td>
<td>(-2.27)**</td>
<td>(-1.77)**</td>
<td>(0.48)</td>
<td>(-4.37)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.513</td>
<td>-0.004</td>
<td>0.006</td>
<td>-0.080</td>
<td>-0.065</td>
<td></td>
<td></td>
<td></td>
<td>-6.13</td>
</tr>
<tr>
<td></td>
<td>(1.50)</td>
<td>(-0.38)</td>
<td>(0.57)</td>
<td>(-2.37)**</td>
<td>(-1.96)**</td>
<td></td>
<td></td>
<td></td>
<td>(-4.83)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.589</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADJUSTED $R^2$</td>
<td>0.407</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{8,19}$</td>
<td>3.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DURBIN'S H</td>
<td>-0.02946</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.582</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$F_{5,21}$</td>
<td>5.837</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-W</td>
<td>1.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 18 df for Model 1 and 21 df for Model 2 statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

** T-statistic significant at a 5 percent level, same df and testing as at 1 percent.
Table 21. Re-Estimation of Models 3 and 4 Based on Testing Results for Coefficient Structural Change with a Dependent Variable of HAA.

<table>
<thead>
<tr>
<th>Model</th>
<th>Intercept</th>
<th>EOAA</th>
<th>LAA</th>
<th>RF</th>
<th>RF_{lag}</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.366</td>
<td>0.028</td>
<td>-0.077</td>
<td>-0.060</td>
<td>-6.46</td>
<td>(-2.48)**</td>
</tr>
<tr>
<td></td>
<td>(1.52)</td>
<td>(1.45)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 28</td>
<td>R^2 = 0.6097</td>
<td>Adjusted R^2 = 0.542</td>
<td>F_{4,23} = 8.98</td>
<td>D-W = 1.92</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Intercept</th>
<th>EOAA</th>
<th>LAA</th>
<th>RF</th>
<th>RF_{lag}</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.406</td>
<td>0.090</td>
<td>-0.062</td>
<td>-0.057</td>
<td>-6.41</td>
<td>(-1.87)**</td>
</tr>
<tr>
<td></td>
<td>(1.72)**</td>
<td>(1.52)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 28</td>
<td>R^2 = 0.613</td>
<td>Adjusted R^2 = 0.546</td>
<td>F_{3,24} = 9.118</td>
<td>D-W = 1.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T-statistic with 23 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated—otherwise two-tail test.

** T-statistic with 23 df significant at a 5 percent level, same testing as at 1 percent.
and a structural change occurs in RF coefficients with the Refuge reduction policy. This interdependence influence is based on cumulative lagged responses from two years of Refuge reductions to increased alfalfa hay acreage.

The explanatory power of each model is moderately high. Model 1 has the lowest adjusted $R^2$ at 0.407, and its F-statistic ($F_{8,18} = 3.23$) rejects a null hypothesis of all coefficients equal to zero at a five percent level. Other models have greater explanatory power. Adjusted $R^2$ values range from 0.482 (Model 2) to 0.546 (Model 4). F-statistics for Model 2 through 4 reject a null hypothesis of all coefficients being zero at an one percent significance level.

Without block-diagonal format, multicollinearity is no longer a problem. Maximum condition index numbers are under four in each model. The largest index is 3.53 for Model 1. Eigenvalues are calculated with correlation matrices. Violations of other OLS assumptions are not problems in model estimation. D-W statistics (Durbin’s $H$ for Model 1) do not reject a null hypothesis of no autocorrelation. Further, all tests for heteroskedastic disturbance terms are rejected in each model.

Other items of note for the equations presented in Tables 20 and 21 are: a) Highly significant D1 coefficients; and b) statistical insignificance of coefficients for price expectation and economic growth variables in each model. The D1 dummy variable attributes a six to six and a half thousand acre reduction in alfalfa hayland to flooding of Malheur and Harney Lakes. By 1983, roughly 10,300 acres of potential hayland (Soil Conservation Service productive land
classes I through IV) had been lost to flooding (Obermiller, 1986). The D1 coefficient estimate is within this loss figure. However, the D1 coefficient estimate is probably on the high side given that only 23 percent of all 1982 hay acreage in Harney County was alfalfa.

Variables used to represent changes in price expectations and economic growth do an uniformly poor job of explaining variation in Harney County alfalfa hay acreage (HAA). Whether explanation is by theory (adaptive or naive price expectations of Models 1 and 2) or by proxy variables of Models 3 and 4, none of these variables has a statistically significant coefficient.

For Models 3 and 4, statistically insignificant proxy variables show that Harney County alfalfa hay acreage changes are different from acreage changes in Eastern Oregon and Lake County. With statistically negative coefficients, RF variables explain this difference. Thus, changes in the Refuge grazing program explain how HAA differs from changes in alfalfa hay acreage changes elsewhere in Eastern Oregon. This is supportive of the market interdependence hypothesis.

Before compatibility testing from survey data, model selection techniques are used to judge which model best represents (3.5). Selection is done with model specification testing for these non-nested regression models. Testing is based on two separate families of hypotheses:

\[ H_0 : \ HAA = Xb_0 + u_0 ; \quad u_0 \ N(0, \sigma^2 * I) \]

\[ H_1 : \ HAA = Zb_1 + u_1 ; \quad u_1 \ N(0, \sigma^2 * I) \]
where \( H_0 \) represents Model 1, 2, or 3 and 4. Depending on \( H_0 \), \( H_1 \) represents other models with different price expectations and economic growth variables.

Models 3 and 4 are tested together because they both represent an unspecified mechanism of change when proxy variables EOAA and LAA are used to explain HAA. These models are postulated to have a different error term structure than Models 1 or 2. However, because these proxy variables are assumed to account for similar factors, the error structure of Models 3 and 4 is not different. Since Models 1 and 2 have different specified price expectations, their error structures are assumed to be different.

A testing procedure from Pesaran (1974, 1982) specifies a test statistic for the above hypotheses. When the null hypothesis is true, this test statistic is approximately distributed as a standard normal random variable. By testing both \( H_0 \) and \( H_1 \) as null hypotheses, possible outcomes could reject \( H_0 \), \( H_1 \), or both as well as not reject both, one, or neither of the hypotheses.

Results in Table 22 show Models 1 and 2 are strongly rejected by both Models 3 and 4. Model 1 also rejects Model 2. While Model 2 is rejected by all models as a null hypothesis, it does not reject any other model as a null hypothesis. Conversely, as null hypotheses, Models 3 and 4 are not rejected by either Models 1 or 2. Thus, this technique gives a recommendation for Models 3 and 4 over Models 1 and 2.

To supplement model selection techniques, comparisons between Models 3 and 4 are done with adjusted \( R^2 \) values and F-statistics from
# Table 22. Model Selection Testing with Student’s t Distributed Test Statistic from Pesaran (1982).

<table>
<thead>
<tr>
<th>Alternative Hypothesis</th>
<th>Null Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
</tr>
<tr>
<td>Model 1</td>
<td>-</td>
</tr>
<tr>
<td>Model 2</td>
<td>-1.17</td>
</tr>
<tr>
<td>Model 3</td>
<td>-21.08*</td>
</tr>
<tr>
<td>Model 4</td>
<td>-15.26*</td>
</tr>
</tbody>
</table>

* T-statistic can reject the null hypothesis at a 1 percent significance level.

a) Extremely large, negative number with denominator near zero.
Table 21. Models 3 and 4 have very similar adjusted $R^2$ values (0.542 and 0.546) and F-statistics ($F_{4,23} = 8.98$ and 9.12). While Model 4 has slightly greater explanatory power than Model 3, both models are chosen as appropriate representations to explain variation in changes in Harney County alfalfa hay acreage. Each model is tested for compatibility with survey information.

As final test of Refuge influence on alfalfa hay acreage in Harney County, compatibility between survey data and econometric estimation is examined. As presented earlier, survey information on permittee response to Refuge forage reductions estimates a -0.064 value for the RF coefficients--i.e. 64 acres developed for every 1,000 AUMs reduction in Refuge grazing supply.

The -0.064 restriction from survey data represents the total influence from Refuge forage reductions. This influence includes all lagged responses. To make this restriction comparable to RF and RF$_{lag}$ variables, a sum of their coefficients is restricted to be equal to -0.064. With RF + RF$_{lag}$ coefficients restricted to -0.064, Models 3 and 4 give restriction F-statistics of:

<table>
<thead>
<tr>
<th>Model</th>
<th>F-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>$F_{1,23} = 3.038$</td>
</tr>
<tr>
<td>4</td>
<td>$F_{1,23} = 1.561$</td>
</tr>
</tbody>
</table>

Both of these F-statistics do not reject a null hypothesis of no difference ($F_{1,23,.05} = 4.28$) between coefficient estimates. These results show that survey information and econometric modelling are
compatible sources of estimation for the Refuge grazing program influence on Harney County alfalfa hay acres.

A nonrejection of this restriction is surprising. Coefficients estimates for RF and $RF_{lag}$ are over twice the size of survey estimated influence on alfalfa hay acreage. Econometric estimates are for a total Refuge reduction influence of -0.137 in Model 3 and -0.118 for Model 4 (Table 21). These estimates translate into a total response of 118 to 137 alfalfa hay acres developed for every one thousand AUMs reduction in RF. Total influence on each year's change in Harney County alfalfa acres is estimated to result from forage reductions in the previous two Refuge grazing seasons.

In sum, reductions in Refuge forage supply have a statistically significant influence on development of alfalfa hay acreage in Harney County. All models show statistical significance at two levels of testing for market interdependence: 1) Negative coefficients for RF variables; and 2) structural changes in RF coefficients before versus after a Refuge forage reduction policy. Both of these results are expected under the market interdependence hypothesis. Survey results are supportive of econometric estimation. Both survey and econometric estimates are for a substantial Refuge influence on alfalfa hay acres. These estimates range from 64 acres (survey data) to 137 acres (econometric estimation) of alfalfa hay being developed for every 1,000 AUMs reduction in Refuge forage supply.
Alfalfa Hay Price Influence

An immediate influence on Harney County alfalfa hay prices from Refuge forage reductions is evaluated with Equation (3.6). In this equation, real hay prices (HP) are a function of hay production (H), cattle numbers (C), and change in Refuge supply (RF). Following market interdependence theory, RF has a negative coefficient. The RF coefficient is statistically less than zero and provides evidence for interdependence.

Like (3.5), Equation (3.6) is estimated in block-diagonal format. A coefficient structural change is expected from a Refuge forage reduction policy initiated in 1973 and changes in the national agricultural economy. Given time of HP measurement (July to next July) and immediate influence of RF, both structural changes occurred in 1973.

Similar to estimation of (3.5), plotting of HP and RF over 1973 to 1986 shows a negative relationship (Figure 14). The OLS regression estimates confirm this negative relationship (Table 23). The RF coefficient is negative and statistically significant for 1973-86. With a T-statistic of -1.763, a null hypothesis of the RF coefficient being equal to zero is rejected in one tail test ($t_{19,.05} = 1.729$).

The statistical significance of the RF coefficient in (3.6) is not tempered by violations of OLS assumptions. A D-W statistic and chi-square statistics from $e^2$ regressions do not reject the null hypotheses of no autocorrelation and homoskedasticity, respectively. Condition index calculations from covariance matrix eigenvalues give
Figure 14. Plot of Changes in Refuge Provided Forage and Real Alfalfa Hay Prices in Harney County, 1973-86.
Table 23. Block-Diagonal Estimation of Alfalfa Hay Price Equation for Harney County with a Dependent Variable of HP.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Intercept</th>
<th>H</th>
<th>C</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-72</td>
<td>81.23</td>
<td>-0.476</td>
<td>0.233</td>
<td>-0.097</td>
</tr>
<tr>
<td></td>
<td>(1.56)</td>
<td>(-1.39)</td>
<td>(0.49)</td>
<td>(-0.36)</td>
</tr>
<tr>
<td>1973-86</td>
<td>91.24</td>
<td>-0.927</td>
<td>0.649</td>
<td>-0.713</td>
</tr>
<tr>
<td></td>
<td>(2.09)**</td>
<td>(-4.76)*</td>
<td>(1.80)**</td>
<td>(-1.76)**</td>
</tr>
</tbody>
</table>

N = 27 \quad R^2 = 0.719 \quad \text{Adjusted } R^2 = 0.615 \quad \text{D-W} = 2.04

* T-statistic with 19 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

** T-statistic with 19 df significant at a 5 percent level, same testing as at 1 percent.
a maximum of 4.17. This maximum is far below a problem level suggested by Johnston (1984). Adverse impacts from multicollinearity are further discounted by the statistical significance of coefficients for all four variables in the second period.

In testing for structural changes, only a \( F \)-statistic for intercept terms is statistically significant:

<table>
<thead>
<tr>
<th>Structural Change Coefficients</th>
<th>F-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>( F_{1,22} = 18.735 )</td>
</tr>
<tr>
<td>H and C</td>
<td>( F_{2,23} = 1.148 )</td>
</tr>
<tr>
<td>H</td>
<td>( F_{1,23} = 1.586 )</td>
</tr>
<tr>
<td>RF</td>
<td>( F_{1,23} = 1.943 )</td>
</tr>
</tbody>
</table>

In contrast to a highly significant structural change in the intercept term (\( F_{1,22,.01} = 7.94 \)), none of the other variables have statistically significant differences in coefficients between time periods. Nonsignificance for RF coefficients is not supportive of market interdependence expectations.

A statistically significant intercept term shift in (3.6) confirms findings by Myer and Yanagida (1984). This shift means that significantly higher alfalfa hay prices occurred after 1973 compared to the 1960-72 period. This structural change in the Harney County alfalfa hay market is postulated to be caused by national economic factors such as energy price increases, Russian grain trade, and agricultural price inflation.

Re-estimation of (3.6) with only the intercept term in block-diagonal form confirms the statistical significance of RF (Table 24).
Table 24. Re-Estimation of Alfalfa Hay Price Equation for Harney County to Account for Significant Structural Change in the Intercept Term with a Dependent Variable of HP.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Intercept</th>
<th>H</th>
<th>C</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-72</td>
<td>69.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.39)**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1973-86</td>
<td>104.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.96)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960-86</td>
<td>-0.790</td>
<td>0.443</td>
<td>-0.796</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-4.83)*</td>
<td>(1.59)</td>
<td>(-2.05)**</td>
<td></td>
</tr>
</tbody>
</table>

N = 27   \( R^2 = 0.686 \)   Adjusted \( R^2 = 0.629 \)   D-W = 1.87

* T-statistic with 22 df statistically significant from zero at a 1 percent level, one-tail test where a coefficient sign is postulated--otherwise two-tail test.

** T-statistic with 22 df significant at a 5 percent level, same testing as at 1 percent.
The RF variable is estimated in Table 24 with zeroes to 1972 and the values of Refuge forage changes after 1972. This estimation format is done to conform with theoretical considerations that RF's influence on alfalfa hay prices occurs after initiation of a forage reduction policy. As a final estimate, the RF coefficient in Table 24 implies that real alfalfa hay price has an immediate increase (within the same year as Refuge reductions) of approximately $0.80 for each 1,000 AUM reduction in Refuge forage supply.

The Refuge influence on alfalfa hay price shows market interdependence at the primary level of testing—a statistically significant, negative coefficient. A significant structural change in the RF coefficient is not found. Only an intercept term shift represents a significant structural change, which confirms prior alfalfa hay price research findings.
CHAPTER V

INTERPRETATION OF RESULTS AND
BLM/FS FORAGE PRICING MOTIVATIONS

This chapter is divided into two distinct sections. The first part contains an expanded discussion of empirical results in Chapter IV. Explanations are given for support and non-support of market interdependence in three public/private forage markets.

In the second section a hypothesis is presented on BLM/FS bureaucratic pricing motivations for Federal forage. This hypothesis is that bureaucrats use forage pricing to promote what they believe is in the public interest, i.e. conservation of public rangeland resources and their long-term, sustainable forage production. The result of this section is to explain why Federal administrators have chosen (and may continue) to ignore the existence of interdependent public/private markets.

Interpretations of Results

The purpose of this section is twofold. First, reasons are examined for non-support of market interdependence in Models A and B. The importance of no evidence for market interdependence is explained for both BLM/FS and Refuge forage pricing.

For Model B only, Harney County forage lease rates are compared to grazing land lease rates for the entire state of Oregon. This comparison is made to examine this county's forage lease rate changes
during the 1970s and 1980s compared with lease rates unaffected by Refuge forage reductions.

In the second portion, statistically significant evidence for market interdependence in Model C testing is examined in regard to pricing of Refuge forage. This result also is related to BLM/FS forage pricing.

**Explanation of No Evidence for Market Interdependence in Models A and B**

As is mentioned in Chapter III, no support for market interdependence from BLM/FS forage markets is attributed to two data problems: 1) Too much aggregation in available state level data; and 2) a lack of dramatic reductions in BLM/FS permitted grazing use. Both of these problems stem from no "official" BLM/FS policy for reducing public land livestock grazing over a state or nationwide basis.

The coefficients in Model A are estimated with readily available, state aggregated data. Aggregation is a problem in these estimation and testing procedures because a uniform Federal grazing reduction policy has not existed over entire states. Without a uniform policy, several difficulties are postulated to arise.

First, without an "official" policy, Federal grazing reductions at a state level are not large and continuous over an extended time period. This is evidenced for Pacific Northwest states in Figures 5 through 7. Second, some market areas have experienced little or no reductions of Federal grazing while other areas incur substantial
grazing reductions. Differences between areas stem from Federal grazing reductions occurring at local BLM District and FS National Forest levels. Private grazing land lease markets are relatively local around Federal lands (Williams, 1969). Given this locality of markets, interdependence is hypothesized to be harder to detect with aggregation of Federal grazing reduction influenced and non-influenced lease markets.

Given the estimation difficulties associated with Model A, future testing for evidence of market interdependence should be done in a study area with an implemented public market policy of forage quantity reduction. A case study with substantial changes in the grazing program, like the Malheur National Wildlife Refuge in Harney County, Oregon, is highly recommended for productive research and testing of public/private forage market interdependence.

With a substantial public forage reduction on the Refuge, data problems in Model B come from an entirely different source. These problems are related to calculation of forage land lease rates. Lease rates are derived from Harney County agricultural land use value assessments. Land use assessments are not solely computed from lease rate information in the Harney County market. Assessments have local political considerations built into final value decisions. Political considerations come in the form of County Assessor's judgment on whether changes in assessed values (as calculated from lease rate information) might be acceptable to county residents.

In addition to concerns about political judgments in the lease rate data, annual sampling of private forage land lease market
probably is not very consistent over the data set. Lease market sampling is done by the Assessor's Office based on a perceived need to update lease information. Sampling is not done annually with a consistent sampling design.

In sum, lease rates derived from assessed agricultural land use values are the best available time series data on Harney County private forage land lease rates. However, because of the above data problems, the level of data accuracy is not conducive to statistical testing by experimental methods. Since lease rate data do not readily support market interdependence in Model B, further data manipulation by generalized least squares is not warranted to correct for problems with OLS violations.

Difficulties in finding evidence for interdependent markets extend beyond data problems for Models A and B. Two of market structure problems are theorized to be present with private grazing land lease markets. These structural problems include: 1) Private forage land lease markets are difficult for non-participants to enter; and 2) land leasing markets consist mainly of individuals dealing informally with one another such that buyers and/or sellers are often able to influence lease rates either by negotiation skills or by nonbusiness relationships between lessee and lessor.

This first problem is apparent from survey responses on why permittees did not lease private land. Some survey respondents have a perception that this market is unavailable (and if available, unaffordable) to them. Because little research has been done on forage lease markets, it is theorized that two factors cause lease
unavailability: 1) Land leases tend to be long-term in nature; and 2) a common bond between lessor and lessee is often required to enter lease markets.

While many leases have a one year term, lessors and lessees commonly extend their leasing agreement past the initial year. Available data support this long-term nature of leasing. In a survey of grazing land leases in 17 Western states, the average lease term was found to be about two years, yet the average leasing history between lessor and lessee was eight years long (Tittman and Brownell, 1984). For Harney County forage land leases, lease history averages five years based on a survey conducted by Obermiller and Collins (1988).

The second factor in lease unavailability ties the two market structure problems together. A prior common bond between lessor and lessee is often required before a lessee is able to lease forage land. Because many lessors no longer live on the lease property, they have to trust in the land stewardship capabilities of lessees. Thus, lessors tend to lease to those whom they know personally or with whom they have had prior business transactions. A common bond factor limits lease availability to potential lessees, for example those individuals who may lose public grazing privileges. This common bond also introduces one reason why each party may have an ability to influence lease rate outcomes. Prior knowledge of the other party in a lease transaction allows for individuals to influence lease rates.
The second problem of each party having the potential to influence lease rate outcome is much like real estate markets (Boyce and Kinnard, 1984). An ability to influence lease rates violates assumptions of competitive market conditions. Violation of price-taker assumptions makes economic analysis under conventional competitive market assumptions less meaningful. Competitive market assumptions are used implicitly in the formulation of all models.

Despite the theorized market structure problems of limited lease availability and parties able to influence price, prior research results discount these problems in economic analyses of grazing land lease markets (Roberts, 1967). Roberts uses competitive market assumptions for grazing land lease markets in Utah to successfully test an hypothesis of use cost equalization between Federal and private grazing leases. Thus, these problems have not impeded previous research on grazing land lease markets, or at least have not been recognized as important impediments.

The importance of non-support for market interdependence in Model A stems from the original research need of public/private forage market connections—pricing of BLM/FS grazing with private grazing land lease market data. However, a lack of statistical evidence for the existence of interdependent markets in Model A does not mean there is no interdependence between these two markets.

In this thesis, emphasis is placed on estimation and testing for evidence of interdependence in those instances where changes in public market quantities are substantial enough to show the presence of market interdependence. Since the existence of market inter-
dependence is determined by the size of Federal forage markets relative to private markets, no evidence of market interdependence can be explained in either of two situations. Either interdependence does not exist between public/private markets or public market quantity changes have not been substantial enough to show its existence in statistical testing. Given no "official" BLM/FS reduction policy over the study area of Pacific Northwest states, a lack of substantial public market changes is attributed to the no evidence for market interdependence.

No evidence of interdependent markets in Model B is important because Refuge management uses a survey of Harney County forage land lease rates to establish forage fees (Obermiller and Collins, 1988). With no market interdependence, average lease rates are not influenced by Refuge forage supply decisions. However, thesis results do not necessarily imply that the private forage land lease market is an appropriate source of pricing data.

While lease rate data and market structure problems mentioned above exist, perhaps the primary reason for interdependence non-support in Model B is that leasing of forage land was not a common ranch management response to Refuge forage reductions. Permittee survey results show leasing to be third among responses (behind buying hay and land) when ranch managers employed resources outside their operation in response to permit changes. This low level of response shows that leasing is not regarded by permittees as a
suitable substitute for Refuge grazing permits.\textsuperscript{1} Whether for reasons of lease unavailability or perceived unaffordability, the Harney County forage land lease market is not a common substitute forage market for Refuge grazing.

The Refuge permittee survey total of 1500 head of cattle placed on leased land is minor compared to Harney County lease market totals. Based on data from Tittman and Brownell (1984), total cattle on leased land during 1982 was about 15,000 head. With the leased land management response occurring over a period of years (1974-81), this influence would be minor on private lease rates.

The principle of substitution between public and private resources logically is a prerequisite for the comparable market method of pricing public forage. In this research, a statement of no market interdependence is appropriate when such a conclusion is based on private market resources that are commonly substituted for public resources. When private forage substitutes for public forage, statistically insignificant influences of public market quantity changes on private market characteristics are evidence of no market interdependence.

Non-support for market interdependence in the Harney County forage land leasing market is judged to result from little substitution between private leasing and Refuge forage resources. A

\textsuperscript{1} In this instance, substitute means replacement within a grazing season of Refuge forage with private forage land leasing. Forage quality comparisons between these two forage sources is not intended by use of the word substitute. Most private sources of forage (especially hayland) are of superior quality compared with Refuge forage due to use restrictions on the Refuge.
no market interdependence judgment is made based on leasing not being a common substitute for Refuge forage. This conclusion has negative connotations for provision of comparable market data by the forage land lease market to price Refuge forage. The comparable market should provide a forage replacement, and the forage land lease market does not provide this for Refuge forage based on actual permittee responses.

Finally, in Model B, Harney County forage land lease rates from 1972 to 1986 are regressed against Oregon grazing lease rates from Model A. This comparison is a check of lease rate patterns in Harney County during Refuge forage reductions compared to lease rates unaffected by Refuge changes. Results show that variation of nominal lease rates in Harney County is typical of rates in Oregon. A high degree of correlation is observed between Harney County rates and rates over the entire state of Oregon:

\[
\text{Harney County} = -0.871 + 0.763 \times \text{Oregon lease rates} \\
R^2 = 0.875 \quad F_{1,13} = 91.34 \quad D-W = 1.28
\]

T-statistics in parenthesis show that Oregon lease rates are a statistically significant explanatory variable for Harney County rates.

In other comparison tests for how Harney County lease rates, the coefficient for Oregon lease rates is significantly less than one. A F-statistic for this restriction \(F_{1,13} = 8.818\) rejects a null hypothesis of this coefficient being one at a five percent significance level. Also, the intercept term is not significantly
different from zero. A significant, positive intercept term or an Oregon lease coefficient greater than one both would lend support to market interdependence. Rejection of null hypotheses in either test would show higher lease rates in Harney County. Neither test rejects the null hypothesis--supporting a lack of connection between Refuge reductions and forage land lease rates in Harney County.

Statistically Significant Evidence for Market Interdependence in Model C

Estimation and testing of coefficients in Model C provides statistically significant evidence of market interdependence. Testing for Refuge impacts occurs at two levels: 1) A negative coefficient for Refuge forage variables (RF) in explanation of variations in hay market acres and prices; and 2) a structural change in RF coefficients before versus after initiation of a Refuge reduction policy. These two levels of testing are akin to necessary (negative coefficient) and sufficient (structural change) conditions for market interdependence under an implemented "official" public forage reduction policy.

Market interdependence implies that necessary conditions exist, but necessary conditions do not imply market interdependence. For example, market interdependence theory implies a negative RF coefficient. However, a negative RF coefficient can be evidence of equation misspecification factors, such as drought conditions where public market supplies decline and forage prices increase.
To be a sufficient condition, significant structural changes in RF coefficients always must imply interdependence. Yet, structural change is not required for market interdependence. A coefficient structural change acts as sufficient conditions and negative coefficients do not because of model misspecification. A statistically significant structural change shows a change in RF coefficients with implementation of Refuge reduction policy, always implying interdependence. Because structural change testing requires data prior to the reduction policy, chances of model misspecification are lowered compared with a negative RF coefficient. Thus, structural change serves as a sufficient condition for market interdependence.

The hay price equation provides an example of structural change being only a sufficient condition. A significant, negative coefficient for RF exists, but the RF coefficient does not exhibit a significant structural change.

Together, necessary and sufficient conditions for market interdependence are fulfilled when public market forage variables have significant negative coefficients and these coefficients experience a structural change with initiation of a quantity reduction policy. Both these conditions are fulfilled by the Refuge forage reduction influence Harney County alfalfa hay acreage, Equation (3.5). However, only necessary conditions are met for alfalfa hay prices (Equation (3.6)).

Estimation by econometric modelling shows two statistically significant influences on the Harney County alfalfa hay market: 1)
Lagged acreage increases of 118 to 137 acres; and 2) immediate real price increase of $0.80 per ton. Both influences are for every 1,000 AUM reduction in Refuge forage.

Increases in Harney County alfalfa hay acreage are explained by Refuge forage reductions (RF) via significant, negative coefficients. These RF coefficients are the result of both: a) permittee replacement of Refuge forage with developed alfalfa hayland on their own operation; and b) development of alfalfa hayland due to Refuge created expectations of future price increases by permittees and non-permittees. In the first instance, a non-hay market price stimulus motivates development of alfalfa hayland. Hay production is secondary to the cattle part of a permittee’s operation. From a cattle perspective, alfalfa hayland is required to seasonally balance an operation when late fall/winter Refuge forage is lost. From a price expectation basis, Refuge reductions are the stimulus for expecting higher alfalfa hay prices in the future due to increased permittee hay demand. Anticipations of higher prices motivates increased development of alfalfa hayland.

Econometric estimates of hay acreage influences from RF are high compared to a 64 acres per 1,000 AUM reduction estimate from survey data. When translated into a cumulative impact during Refuge policy of reduction (from 1973 to 1982), Harney County alfalfa hay acreage increases are 9,600 to 11,200 for econometric estimates and 5,200 for survey estimates. These acreage increases are based on Refuge reductions of about 82,000 AUMs (122,000 averaged from 1970-73 minus 40,000 in 1982). The total change in Harney County alfalfa hay
during 1973 to 1982 was 14,900 acres. Thus, Refuge influence estimates account for about 1/3 to 2/3 of this total. While the "true" influence probably is somewhere between these two estimates, these estimates show that the Refuge influence is substantial on changes in Harney County alfalfa hay acres.

The influence of RF on real alfalfa hay prices also is substantial compared to increased hay production. Both variables have coefficients of -0.80. However, RF is measured in 1,000 AUM units, and hay production is measured in 1,000 ton units. A ton of hay has roughly two and one-half times as much forage as an AUM, and not every Refuge AUM is replaced by purchased alfalfa hay. Thus, each unit of hay production is much larger than Refuge AUM. Based on coefficient estimation in (3.6), alfalfa hay price impacts are greater when there are sudden increases in demand caused by Refuge reductions than when these are changes in alfalfa hay production.

Evidence of market interdependence in Model C applies to both Federal forage pricing examples. These examples are appraisal of permittee use value and first best, Pareto optimal pricing in the Federal forage market.

Under price establishment at use value, the existence of market inter-dependence implies a violation of the fundamental appraisal assumption. This violation means that if public and private forage markets are combined, then private market exchange value would change. Significant structural change and negative RF coefficients are evidence that the size of the Refuge forage market and its permittees influence the private alfalfa hay market price and
quantity. If these markets were combined at the Refuge forage level prevailing before reductions occurred, alfalfa hay exchange value would have changed.

RF coefficients statistically different from zero show that nonzero cross price/quantity and cross quantity/quantity elasticities exist between private and public markets. Non-zero cross price elasticities violate sufficient conditions put forth by Boadway and Harris (1977) for appropriate "piecemeal" Pareto optimal, first best pricing. To apply this research to Boadway and Harris' results, one must extend non-zero public forage quantity impacts to pricing impacts. Such an extension is presented in Chapter II.

As presented earlier (Equations (2.11) to (2.13)), non-zero price/quantity elasticities results of this thesis infer a non-zero relationship between Federal forage prices and private forage demand. This inference also requires a non-zero relationship between Federal forage prices and Federal forage quantities utilized by permittees. This relationship has been established by Johnson and Watts (1988) for BLM grazing.

With these Chapter II connections, the Boadway and Harris results can be applied to pricing of Refuge forage resources. These results mean first best pricing of Refuge forage at marginal cost is not an appropriate policy. Market interdependence means that sufficient conditions are not met for a social welfare improvement with "piecemeal" pricing.

Results from Model C show the existence of market interdependence in Harney County between the private alfalfa hay market and
Refuge grazing program. However, these results do not suggest what type of adjustment in private market data can be made to facilitate use of private market data to price public resources under market interdependence. For example, to infer public forage prices from permittee use values, private market exchange values are used in the comparable markets method. Under interdependent markets, simulation modelling of private market supply and demand functions is necessary to estimate the influence of public market supply and demanders on private market characteristics.

While Model C does not provide this type of simulation information, estimation of a $0.80 increase in real hay price for every 1,000 AUM reduction from last year’s Refuge forage quantity could be used to adjust private market data for the influence of market interdependence. However, such an adjustment, if made, is strictly a "best available information" situation. Given the non-marginal nature of combining markets, time and monetary costs would be high for obtaining simulation modelling results. The cost of adequate simulation information may not justify a more precise estimate of exchange value under combined markets. Thus use of hay price model information in adjusting private market data would be justified only if costs of obtaining better information exceed the benefits.

As for Refuge case study applicability to market interdependence for BLM/FS grazing programs, both of these public forage markets are of substantial size when compared with private markets. Between 1970-73, annual average forage quantities for the Refuge and Harney County alfalfa hay markets were 122,000 AUMs and 43,300 tons,
respectively. With a conservative conversion ratio of 2.5 AUMs per ton of hay, the public/private market size ratio was 1.13 before Refuge reductions began.

This 1.13 ratio for public/private market size in Harney County is less than public/private market size ratios for BLM/FS grazing and private grazing land lease markets. As mentioned in Chapter II, there are 300 million acres of BLM/FS grazing land leases compared to 100 million acres of non-Federal leased grazing land in the western United States. Certainly, if market interdependence is found in Harney County with a 1.13 ratio, then a ratio approaching 3.0 for BLM/FS grazing programs on an aggregate basis (with many localities being much higher) strongly implies existence of market interdependence between BLM/FS and private lease markets in the west.

The purpose of this research is to investigate evidence for market interdependence. Statistically significant evidence of interdependence is found in estimation and testing of coefficients in Model C. The Harney County case study provides an example of evidence for market interdependence by use of historical data. It is hoped that these research results will be considered as Federal grazing fee (specifically BLM/FS grazing fees) issues are debated. An influence similar to work by Roberts (1967) is envisioned for these research results. Roberts' research uses historical data to statistically validate the concept of use cost equalization between public and private grazing leases. Results from Roberts' research have been incorporated into Federal grazing fee formulas. Perhaps, in the future, a similar degree of consideration can be given to
market interdependence when proposed Federal grazing fees involve the use of private market data. This research provides a beginning for this consideration by showing the existence of market interdependence in public/private forage markets.

**Federal Bureaucratic Pricing Motivation**

A Federal forage pricing motivation for BLM/FS bureaucrats is explored in this section. An attempt is made to explain why these administrators have chosen to ignore market interdependence in recent appraisals of forage values (Tittman and Brownwell, 1984) and in their recommendations of Federal forage pricing formulas using comparable market methods (U.S. Department of Agriculture and the Interior, 1986). Once a pricing problem such as market interdependence has been theoretically identified and demonstrated to be statistically significant based on historical data, then there should be motivation on the part of Federal agency administrators to address this problem. However, this section shows that this motivation has been and may continue to be lacking.

Bureaucratic motivations are examined in many self-interested behavioral models in the literature (examples include Stroup and Baden, 1983; Peltzman, 1976; Niskanen, 1971). A common theme among these models is that bureaucrats manage government agencies for their own self-interest (be it budget size or political support) rather than a specified public interest, like the welfare maximization objective presented earlier. In this section, however, it is argued
that bureaucratic motivations for Federal land management are to promote what they perceive is in the best interest of society (the general public).

For BLM/FS agencies, land managers' perceptions of public interest are assumed to be conservation of the land resource and the long term sustainability of its productive capacity. This means that management decisions for public rangelands (like grazing fee policy) are made based on how outcomes from these decisions affect a manager's ability to improve land conservation and long-term sustainability of public forage resources. In this motivational view of management decisions, managerial control of public lands and an ability to improve land resource quality are linked together such that a desire for the former is based on motivations for the latter.

Bureaucratic motivation is important in determination of pricing policy because agency interpretation is required for a statutory directive of "fair market value". The legislative definition of "fair market value" for Federal grazing expired as of December 31, 1985, with the expiration of the Public Rangelands Improvement Act of 1978. The Federal Land Policy and Management Act of 1976 does not provide guidance for determination of "fair market value". Thus, agency interpretation of how to compute this value and what data to use are important in directing ultimate fee policy.

Support for resource conservation as a motivational factor of bureaucratic land management comes from two sources in the literature. Behan (1987) cites public service motivation of Federal land managers as their belief in the importance of what they are
doing and in the social value (necessity) of their mission. In a similar vein, Nelson (1985) states BLM managers feel economic justification for range improvements is not important because "it is morally, ethically, and professionally right to institute management practices that stop erosion, grow better forage and vegetation, and improve rangeland condition and trend" (p. 55). The result is that bureaucratic motivation for improved resource conservation may ignore other societal concerns, such as net benefit maximization or perhaps equity in forage resource pricing given market interdependence, to promote what a land manager perceives to be in the public interest.

Motivation for improved resource conservation enters into the Federal grazing fee policy issue when BLM/FS bureaucrats desire greater management control of livestock grazing on public land. Permitted livestock grazing on public lands is closely tied to historic use levels. This makes dramatic reductions from the status quo difficult to achieve. If managers are dissatisfied with present grazing use, one method to assert greater control is implementation of a fee policy that results in higher permittee costs.

Higher fees would tend to reduce livestock grazing on public lands without a change in permitted use. Nelson (1985) already has pointed out that higher grazing fees lead to increased agency control of public land grazing use. As noted earlier, the recent appraisal of "fair market value" uses private market data without user cost or interdependence considerations (Tittman and Brownell, 1984). The resulting grazing fee options in the 1986 fee report showed sub-
stantial increases from present fee levels (U.S. Department of Agriculture and the Interior, 1986).

Two central public rangeland management issues tie control of livestock grazing to agency desire for higher fees. They are: 1) A general perception that public range lands continue to be in need of improvement, and that present livestock use hinders this improvement due to overgrazing; and 2) the failure of scientific management techniques to give the BLM/FS greater control over livestock grazing use at local district and national forest levels.

The need for continued public rangeland improvement is cited by agency reports on rangeland condition (BLM, 1975; U.S.D.A., 1972) as well as in academic publications (Box, et al., 1976). Livestock's role in hindering rangeland improvement is based largely on documentation of past overuse combined with perceptions expressed in popular literature (Burstein, 1985; Sheridan, 1981).

The second issue, the failure of scientific management, is linked to an inability of BLM and, to a minor extent, FS bureaucrats to cut public land livestock grazing use. Grazing use reductions relieve grazing pressure and improve vegetative conditions of public rangeland. Briefly, scientific management is the use of scientific evidence (such as range forage quantity or rangeland condition) in exercising unbiased, professional judgment in management decision-making (Bradley and Ingram, 1986). This rational form of decisionmaking has been a part of Federal natural resource agencies since the administration of Theodore Roosevelt (Hays, 1959).
The beginnings of BLM implementation of scientific management on public rangelands is a successful lawsuit by the Natural Resources Defense Council in 1975 (Bradley and Ingram, 1986). In this lawsuit, BLM was ordered to perform environmental impact statements (EIS) for livestock grazing on public lands. With vegetation and soils information from EIS data inventories, BLM managers employed scientific management techniques at District levels to make recommendations of vegetation allocation among livestock and wildlife. Many of these recommendations called for substantial livestock grazing reductions (Nelson, 1980).

Recommended reductions, however, generally failed to occur. Reasons for this failure are outlined by Nelson (1980), Bradley and Ingram (1986), and Fairfax (1984). They include political pressure by ranchers, lack of a solid scientific foundation for basic range management concepts (like range condition), inadequate environmental data bases collected by BLM personnel, and finally, changing societal acceptance of scientific solutions to problems.

Without an ability to implement significant changes in livestock grazing at the local level via scientific management techniques, it is hypothesized that national fee policy has been substituted by BLM/FS bureaucrats to gain greater control over public land livestock grazing use levels. This desire to control grazing use stems from the bureaucratic motivation to improve land resource conservation. Improved conservation comes from a reduction of livestock grazing use under conditions of perceived overgrazing.
Though present fee levels do influence grazing use, that influence is small. Johnson and Watts (1988) report a price elasticity of -0.2 for BLM livestock grazing use. However, substantially higher nationwide fees (three to four times present fee level) would certainly cause fees to be a major determinant in grazing use decisions by permittees. Limited research exists on Federal grazing use responses to such large fee increases. These increases could result in the level of use reductions recommended in EIS’s. Thus, by use of a centralized fee authority, livestock grazing reductions would be achieved where localized scientific management techniques failed.

In summary, to connect bureaucratic pricing motivation with non-acknowledgement of market interdependence, the following causal flow of circumstances is suggested: a) Bureaucratic motivation to serve perceived public interests by improving public land resource conservation; b) desire to have increased managerial control over the major public rangeland user--livestock grazing; c) with the failure of scientific management to reduce perceived overgrazing on public lands, large increases in the national grazing fee present an alternative method to achieve livestock use reductions; d) a large increase in fees can be obtained by using private lease market data with few adjustments for Federal market differences (U.S. Department of Agriculture and the Interior, 1986); e) the present private market data adjustment is for higher nonfee costs associated with public land use; and f) other possible adjustments in private market data,
such as market interdependence, are viewed by bureaucrats as having a downward influence on calculated fee levels. 

Statement f) is made based on the history of grazing fees controversy. In this history, a great deal of political pressure has been exerted to keep fees low (Culhane, 1981; Secretary of Agriculture and the Interior, 1977; Foss, 1960). In addition, adjustments of public/private market interactions (such as cost equalization) in grazing fee calculations have reduced Federal fee levels in comparison with private lease rates (Secretary of Agriculture and the Interior, 1977).

Thus, market interdependence is viewed by BLM/FS bureaucrats as yet another private market data adjustment. From this perspective, they have chosen and would prefer to continue ignoring the existence of market interdependence. In their view, market interdependence has substantial political support only if this concept lowers Federal fees in relation to private lease rates. BLM/FS bureaucrats do not want Federal grazing fees to be lower than private lease rates. Implementation of fees as close as possible to private lease rates means large fee increases. Since larger fee increases would, in all likelihood, create reductions in public land livestock grazing, private market data adjustments like market interdependence are ignored by BLM/FS bureaucrats to avoid possible lowering of Federal grazing fees in relation to private lease rates.
CHAPTER VI

NORMATIVE PRICING MODEL FOR LIVESTOCK GRAZING ON BL&M AND FS PUBLIC LANDS

The purpose of this chapter is to present an alternative pricing mechanism for Federal livestock grazing fees that does not rely on observed private market lease rates. By not using private market data, this proposed fee mechanism avoids problems associated with comparable markets, dissimilar goods, and market interdependence.

This chapter is a complement to the first five chapters of this thesis. These earlier chapters document that interdependent public/private forage markets exist in a case study of Harney County, Oregon. Also, these results can be extended to BL&M/FS and private grazing land lease markets. The proposed grazing fee mechanism of this chapter is a solution to pricing of Federal forage without having to rely on data from interdependent private forage markets.

With the proposed fee mechanism, economic features taken into consideration for pricing Federal forage include: A) Permittee demand functions for Federal forage; b) tradeoffs between livestock grazing and public good production on Federal land;¹ c) Federal allocation among various public goods (wilderness versus developed campgrounds) and valuation of these public goods. The result is a fee mechanism similar to Ramsey-Boiteux optimal pricing conditions.

¹ As used here, public goods connote those goods or services which are not purely rival so that one agent's use does not preclude use by another agent. As used here, this term includes nonexcludable goods which experience congestion costs, called mixed public goods (Boadway and Bruce, 1984).
under a budget constraint (Ramsey, 1927; Boiteux, 1956). A distinctive feature of this proposed fee mechanism is its use of public good allocation by the public sector (BLM and FS) to assist in determination of fees to charge for public sector production of private goods, i.e. livestock forage.

Finally, to demonstrate the applicability of this alternative fee mechanism, a numerical example is presented in the final section of this Chapter. This example is on FS grazing in Colorado. Data come from published research. Admittedly, this example represents a "back of the envelope calculation" of FS grazing fees. Its purpose, however, is not precise fee calculation but to show that research information exists to calculate grazing fees using the proposed mechanism.

**Calculation of Fee Mechanism**

This alternative fee mechanism is based on a normative model of bureaucratic behavior. The model assumes a two structure system within the public sector: 1) A government to set objectives and constraints; and 2) public enterprises, such as BLM and FS, who willingly carry out these objectives in their production and pricing decisions given governmental dictated constraints. Under this institutional structure, a second best model is formulated the objective of public sector production and pricing is to maximize social welfare (as measured by individual utilities). The second best constraint is a fixed public enterprise budget. The second best allocative constraint for BLM and FS introduced in Chapter II is
incorporated later into this fee mechanism to solve for pricing of livestock grazing.

Following Dreze and Marchand (1976) and Bos (1985), an objective function and the constraints facing public enterprises under a two structure system are:

\[ p, Y, Z \ \text{Maximize} \ \sum_k \lambda_k U_k \left[ q_k(p, r_0^k + \sum_h \theta_h^k p x^h, Z); Z \right] \]  \hspace{1cm} (6.1)

Subject to:

\[ [\alpha] \ \sum_k q_k(p, R_0^k + \sum_h \theta_h^k p x^h, Z) - Y - \sum_h x^h(p) = 0 \] \hspace{1cm} (6.2)

\[ [\beta] \ \ g(Y, Z) = 0 \] \hspace{1cm} (6.3)

\[ [\gamma] \ b - pY = 0 \] \hspace{1cm} (6.4)

Where there are \( k \) individuals, \( h \) firms, \( n \) goods, and

\( \lambda_k \) = weighting of each individual's utility function for a summation to measure social welfare;

\( U_k \) = utility function of the \( k^{th} \) individual;

\( q_k \) = quantity demanded by the \( k^{th} \) individual;

\( p \) = price of private goods;

\( \theta_h^k \) = Distribution of firm \( h \) profits to individual \( k \) where \( \sum_h \theta_h^k = 1 \).

\( r_0^k \) = predetermined transfers which add up to \( b \);
\[ Y = \text{private good production by the public sector}; \]

\[ Z = \text{public good production by the public sector}; \]

\[ X^h = \text{private good production by the h^{th} private firm}; \]

\[ g(\cdot) = \text{public sector production function in private and public good space which takes in account long-term productive capacity of land resource; and} \]

\[ b = \text{government enterprise budget constraint, } b > 0 \text{ dictates a profit be generated while } b < 0 \text{ means a subsidy is provided to the enterprise.} \]

Equation (6.1) is a generalized utilitarian social welfare function. Model assumptions include: 1) Utility and production functions are twice continuously differentiable; 2) Y and X variables are netput vectors where inputs are negative and outputs are positive quantities; 3) market clearing in all markets is assured by an Equality of Equation (6.2); 4) individuals' incomes are not a decision variable for government enterprises so that redistribution transfers by a governmental authority do not occur; and 5) private economy workings are exogenous to government enterprises.

Decision variables for a public enterprise are p, Y, and Z in those sectors of the economy controlled by the public sector. This model dictates that each enterprise observe a budget constraint while serving all demand for its products.

One item of note in (6.1) is that production possibilities for private firms are independent of public sector decisions. As is
shown earlier, this stipulation is not true under interdependent markets. A condition of no interdependence is assumed, however, to facilitate solution of this model using techniques outlined by Dreze and Marchand (1976). An assumption of no market interdependence does not mean that its existence is not assumed away, but rather that its existence is not accounted for in this fee mechanism.

Bos (1985) gives an example of pricing mechanisms which account for interconnections with the private sector. Under a pricing mechanism which accounts for public sector quantity interdependence \( X(p,Y) \) a pricing solution is obtained when an assumption is included that allows the government to continually redistribute income \( r^k \) a policy variable). Redistribution cancels out income effects from price changes. Without this unlikely and impractical assumption, the pricing mechanism requires knowledge of individual utility functions in order for the system of equations to be solved.

Solving for a maximum in Equation (6.1), first order conditions are:

\[
[Y_i] \alpha_i - \beta \frac{\partial q_i}{\partial Y_i} + \gamma p_i = 0 \quad i = 1, \ldots, n \tag{6.5}
\]

\[
[Z_j] \sum_k \lambda^k (u_j^k + \sum_i \frac{\partial q_i^k}{\partial Z_j} ) - \sum_i \alpha_i \sum_k \frac{\partial q_i^k}{\partial Z_j} - \beta g_j = 0 \tag{6.6}
\]

\[ j = 1, \ldots, a \]

\[
[p_a] \sum_k (\lambda^k u_j^k - \alpha_i) \left( \frac{\partial q_i^k}{\partial p_a} + \frac{\partial q_i^k}{\partial r_k} \sum \theta^k (x^h_a + \sum_c \frac{\partial x^h}{\partial p_a}) \right) \tag{6.7}
\]

\[ + \sum_i \alpha_i \sum_h \frac{\partial x^h}{\partial p_a} + \lambda Y_a = 0 \quad a = 1, \ldots, n \quad c = 1, \ldots, n; \ c \neq a \]
To transform these conditions into a solution format for public sector prices and quantities requires the following consumer and producer equilibrium identities:

\[
\frac{U_k}{U_n} = \frac{p_i}{p_n} \quad (6.8a)
\]

\[
\sum_i p_i \frac{\partial q_k}{\partial r^k} = 1 \quad (6.8b)
\]

\[
\sum_i p_i \frac{\partial q_k}{\partial p_a} = -q_a^k, \quad a = 1, \ldots, n-1 \quad (6.8c)
\]

\[
\sum_i p_i \frac{\partial q_k}{\partial Z_j} = 0 \quad (6.8d)
\]

\[
\frac{f_i^h}{f_n^h} = \frac{p_i}{p_n} \quad (6.9a)
\]

\[
\sum_i p_i \frac{\partial x_i^h}{\partial p_a} = 0, \quad a = 1, \ldots, n-1 \quad (6.9b)
\]

Consumer identities in (6.8) come from utility maximization under a budget constraint. Producer equilibrium conditions of (6.9) originate from firm profit maximization given a production constraint.

To start, Equation (6.5) is multiplied by an arbitrary, non-null scalar term, \(P_n/B*\gamma_n\), where \(n\) is an input index for a public sector input which measures costs and productivities. The first order condition in (6.5) for \(Y_i\) becomes:
\[ a_i = -\gamma p_i + \frac{g_i}{g_n} p_n \]  

(6.10)

where

\[ \bar{a}_i = \frac{p_n a_i}{\beta g_n}; \quad \bar{\gamma} = \frac{p_n \lambda}{\beta g_n} \]

Since first order conditions are homogeneous to degree zero in Lagrangian multipliers, this multiplication did not change relationships between multipliers in (6.5).

Next, the first order condition for \( P_a \), (6.7), is transformed to solve for one of two equations in the proposed grazing fee mechanism. By multiplication with the above non-null, scalar term and substitution of (6.10), the result is broken down into two parts to demonstrate which consumer and producer identities are introduced to eliminate terms:

\[
\sum \sum (\bar{\lambda}^k u^k_i - \frac{g_i}{g_n} p_n + \bar{\gamma} p_i)(\frac{\partial q^k_i}{\partial p_a} + \frac{\partial q^k_i}{\partial r^k h} \sum \theta_h^k (x_h^a + \sum p_c \frac{\partial x_h^a}{\partial p_a}) (6.11)
\]

\[ - \sum (\frac{g_i}{g_n} p_n + \bar{\gamma} p_i) \sum \frac{\partial x_h^a}{\partial p_a} + \bar{\gamma} y_a = 0 \]

Part (A) incorporates (6.8) a), b), and c) along with producer identity (6.9) b) to become:

\[
\sum \frac{\bar{\lambda}^k u^k}{p_n} (-q_a^k + \sum \theta_h^k x_h^a) - \sum \sum \frac{g_i}{g_n} p_n (\frac{\partial q^k_i}{\partial p_a} + \frac{\partial q^k_i}{\partial r^k h} \sum \theta_h^k x_h^a) - \bar{\gamma} y_a
\]

Part (B) requires (6.9) b) for a reduction to:
\[ \sum g_i p_n \sum \frac{\partial x_i^h}{\partial p_a} + \gamma Y_a \]

Combining transformed Parts (A) and (B), Equation (6.11) becomes:

\[ \sum k u_k n \left( - q_k^a + \sum \theta_k x^h a \right) - \sum C_{m_i} \left( \sum \frac{\partial q_k^i}{\partial p_a} + \sum \frac{\partial q_k^i}{\partial r_k h} \theta_k x^h a \right) = 0 \]  

\[ \text{Equation (6.12)} \]

\[ \text{Cm}_i \text{ defines a marginal cost of output } i \text{ in public sector production } \left( p_n g_i / g_n \right). \text{ By use of the following identity,} \]

\[ \sum p_i \left( \sum \frac{\partial q_k^i}{k \partial p_a} + \sum \frac{\partial q_k^i}{\partial r_k h} \theta_k x^h a \right) = - \sum q_k^a - \sum x^h a \]

\[ \text{Equation (6.13)} \]

\[ \text{Equation (6.12) is converted into:} \]

\[ \sum (C_{m_i} - p_i) \left( \sum \frac{\partial q_k^i}{k \partial p_a} + \sum \frac{\partial q_k^i}{\partial r_k h} \theta_k x^h a \right) - \sum \frac{\partial x^h a}{h \partial p_a} = \sum q_k^a - \sum x^h a \]

\[ \sum k u_k n (q_k^a - \sum \theta_k x^h a) = \sum (1 - \frac{k u_k n}{p_n} (q_k^a - \sum \theta_k x^h a)) \]

\[ \text{Equation (6.14)} \]
Small m represents a \( m^{\text{th}} \) reference individual. For (6.14), the two terms in brackets describe a market demand for \( Y_a \) based on the private economy's response to public sector price changes on the \( a^{\text{th}} \) private good. If \( Y_a \) is defined in terms of a production input, like livestock grazing, the first term in brackets represents a summation of \( k \) individuals' supply decisions based on price and income considerations. The second term in brackets is firm input demand. Let \( \partial Y_i / \partial P_a \) connote these partial derivative terms in brackets, where - signifies business profits were taken into account.

As a last adjustment on (6.7), let \( L \) denote:

\[
L = \frac{\sum m \mu m}{p_n} = \frac{\lambda m \mu m}{\beta g_n}
\]

Equation (6.14) now becomes part one of two equations required to solve for a grazing fee mechanism:

\[
\sum (Cm_i - p_i) \frac{\partial Y_i}{\partial P_a} = \sum (1 - L \frac{\lambda k u k}{m \mu m}) (q_{-1} k - \sum \theta h \lambda h_a)
\]  

\[(6.15)\]

In order to solve for \( L \) in (6.15), first order condition (6.6) for \( Z_j \) is rewritten by substitution of (6.8a) and multiplication by a scalar \( P_n / g_n * B \):

\[
\sum \alpha k u j = \sum \alpha_i \frac{\partial q_k}{\partial Z_j} + p_n \frac{g_j}{g_n}
\]  

\[(6.16)\]

Substitution of (6.10) along with an identity \( \pi_j^k = p_n * \frac{U_k}{U_n} \) (Dreze and Marchand, 1976) are used to create:
\[ \sum_{k} \pi_{j}^{k} \frac{\lambda_{jk}}{p_{n}} = \sum_{i} (C_{m_{i}} - \gamma_{p_{i}}) \sum_{k} \frac{\partial q_{i}^{k}}{\partial z_{j}} + C_{m_{j}} \]  (6.17)

The identity, \( \pi_{j}^{k} \), represents a standard notation in the literature on public goods. It is an amount of numeraire that an individual \( k \) is willing to pay for an additional unit of public good.

By use of (6.8d) and the \( L \) identity, Equation (6.17) becomes:

\[ \sum_{k} \pi_{j}^{k} \frac{\lambda_{jk}}{\lambda_{m_{j}}^{m_{n}}} = \frac{1}{L} [C_{m_{j}} - \sum_{i} (p_{i} - C_{m_{i}}) \frac{\partial y_{i}}{\partial z_{j}}] \]  (6.18)

where:

\[ \frac{\partial y_{i}}{\partial z_{j}} = \sum \frac{\partial q_{i}^{k}}{\partial z_{j}} \]  (6.18a)

Equality of (6.18a) comes from an assumptions of clearing markets and government meeting all demand changes for private good \( i \) due to \( j \) public good quantity changes.

Equations (6.15) and (6.18) are required to hold as equalities simultaneously with the budget constraint (6.4) for maximize maximum social welfare. The identity \( L \) acts as a budget constraint multiplier. To simplify both (6.15) and (6.18), the ratio of redistribution weights attributed to marginal income transfers \( (\lambda_{jk}^{m_{k}} / \lambda_{m_{k}}^{m_{n}}) \) is assumed to be one. This assumption may be interpreted as acceptance of the prevailing income distribution (Dreze and Marchand, 1976). With this assumption, (6.15) and (6.18) then become:

\[ \sum_{i} (C_{m_{i}} - p_{i}) \frac{\partial y_{i}}{\partial p_{a}} = \bar{\gamma}_{a} \]  (6.19)
\[ \sum_{k}^{\infty} \pi_{j}^{k} = \frac{1}{1-L} \left[ C_{mj} - \sum_{i}^{\infty} (p_{i} - C_{mi}) \frac{\partial Y_{i}}{\partial Z_{j}} \right] \]  \[ (6.20) \]

where \( L = 1 - L \).

This simplification permits a solution without knowledge of individual terms, \( q_{a}^{k} - \sum_{h}^{\infty} \delta_{h}^{k} \alpha_{a} \). As Dreze and Marchand point out, it is difficult to conceive of circumstances where complete knowledge of individual product demands and firm ownership is available.

Brief interpretations of these equations show how they are interrelated. Equation (6.19) represents the "Ramsey-Boiteux conditions" for optimal pricing under a budget constraint. In this equation, private good production by the public sector \( (Y_{a}) \) depends on deviation of price from marginal cost in some private good markets. These private good markets are those where public sector supplies of \( Y_{i} \) are influenced by price changes for good "a". In (6.19), \( L \) plays the role of a budget constraint multiplier.

Because of \( L \), a solution for (6.19) requires (6.20). Equation (34) is based on public good allocation. This equation relates total willingness to pay for a public good to its marginal cost. Subtracted from marginal cost is a term which reflects the difference that would accrue to public sector net profits from production of private goods if \( Z_{j} \) is increased by one unit.

**Numerical Example**

To apply (6.15) and (6.18) to pricing of Federal grazing, several assumptions are employed.
1) Grazing permits are individualized so that they are considered unique and nontransferrable. This allowed for an assumption of \( \partial Y_i / \partial p_a = 0 \) for all \( a \neq i \). This assumption incorporates present legal and institutional Federal grazing constraints into pricing and allocation decision-making. As detailed earlier, Federal grazing permits are tied to specific parcels of private property, giving this assumption short-run validity. Implicitly recognized under this assumption are permit ownership rights as argued by Hooper (1968).

2) Demand for private goods produced by the public sector \( (Y_i) \) is not influenced by public good provision \( (Z_j) \), \( \partial Y_i / \partial Z_j = 0 \) for all \( i \) and \( j \). For Federal grazing and outdoor recreation, this assumption is logical.

3) Income effects were zero, \( \theta_{kn}^{h} = 0 \) due to individualized nature of \( Y \).

By employing these assumptions, (6.15) and (6.18) are converted into:

\[
(C_m k - p_k) \frac{\partial Y_k}{\partial p_k} = q_k^k (1 - L) \frac{\lambda_{kU_k}^n}{\lambda_{mU_m}^n} \quad k = 1, \ldots, m \tag{6.21}
\]

\[
\sum_k \pi_j^k \frac{\lambda_{kU_k}^n}{\lambda_{mU_m}^n} = \frac{C_{mj}}{L} \quad j = 1, \ldots, \epsilon \tag{6.22}
\]

Quantity, price, and marginal cost in (6.21) are indexed to a \( k \)th individual permittee. For an individual \( k \) such that \( \lambda_{kU_k}^n = \lambda_{mU_m}^n \),
(6.21) is written as, after algebraic manipulation:

\[
(Cm_k - P_k) / P_k = \sum Y_k \left( \frac{\partial Y_k}{\partial P_k} \right) = \frac{1}{n_{Y_k pk}}
\]

(6.23)

The term \( n_{Y_k pk} \) is price elasticity of individual k's demand for Federal grazing on his/her permit.

Equation (6.23) represents standard Boiteux conditions for BLM/FS agencies. It says these agencies should behave as discriminating, price setting monopolists who inflate demand elasticities by a factor \( 1/\sum \) which is greater than one.

To apply (6.23) to Federal grazing, data are required for \( n_{Y_k pk} \) and \( Cm_k \). In this example, data are obtained to price FS grazing in Colorado. First, an own price elasticity of -1.0632 for FS summer grazing is obtained from Quigley (1985). Based on 1977 data, this elasticity figure is an arc elasticity measure over changes from 75 to 125 percent of an base price level set. Quigley concludes that arc elasticities are more reflective of observed behavior for ranch operations in Southwest Colorado than point elasticities.

The marginal cost of providing FS grazing is obtained from a cost of information study by Rafsnider, et al. (1983). Using data from Northern Utah and Eastern Idaho, they calculate an annual sampling cost to increase the accuracy of range vegetation survey data. This additional sampling expense represents the cost of additional AUMs of livestock forage on public rangeland, because allocated livestock forage increases with improved accuracy of

\[\text{For Federal forage, the base price level is set at linear programming shadow values due to an institutionally set actual price.}\]
sampling. Based on conservative allocation, livestock use is determined at the low end of confidence intervals around mean forage production on rangeland.

With 1980 costs and at a suggested significance level of 80 percent, improvement of sampling confidence interval from $\hat{u} = 30$ to $\hat{u} = 20$ kilograms per hectare (kg/ha) increases cost by $0.24$ per AUM (Rafsnider, et al., 1983). Improvement to $\hat{u} = 10$ kg/ha shows an additional cost of $0.81$ per AUM. These two costs plus an average ($0.53$ per AUM) are used for a range of values on Cm_j.

With knowledge of n_{Ykpk} and Cm_j, only $\bar{L}$ is needed to determine a forage price ($p_k$) from (6.23). A solution for $L$ is derived from (6.22). The initial step assumes that $\pi_j^k$ and $\lambda_k^u n_{\lambda m}^m$ have a zero covariance. This allows the left-hand side of (6.22) to be written as $\sum_j \hat{\pi}_{jk}$, a summation of compensated willingness-to-pay (WTP). To verify an equality of (6.22) (i.e. assure an optimal level of resource allocation among $Z_j$ goods), the following ratios must be equal:

$$\frac{\sum_k \hat{\pi}_{jk}}{\sum_k \pi_k^k} = \frac{Cm_j}{Cm_\epsilon}$$

(6.24)

If the equality in (6.24) holds, $\bar{L}$ is measured by:

$$\bar{L} = 1 - \frac{Cm_j}{\sum_k \hat{\pi}_{jk}} = \frac{\sum_k \hat{\pi}_{jk} - Cm_j}{\sum_k \hat{\pi}_{jk}}$$

(6.25)

The equality of ratios in (6.24) is verified with resource valuations and marginal costs for two types of outdoor recreation: 1) Wilderness hiking and backpacking; and 2) camping at developed
campgrounds (Walsh and Gilliam, 1982). Forest Service recreation sites are Indian Peaks Wilderness Area and Brainard Lake Recreation Area, both just south of Rocky Mountain National Park.

WTP estimates are based on 1979 data and have congestion costs (based on encounters with other people) deducted from them. As with most WTP research measures, WTP measurements from Walsch and Gilliam are not compensated for income effects. It is assumed that a difference between compensated and uncompensated WTP is small relative to the size of uncompensated WTP.

For wilderness, a weighted estimate based on the number of hikers and backpackers is $13.90 per visitor day. At Brainard Lake, a visitor day of camping is valued at $8.70. These estimates, even deducted for congestion costs, are within a range of outdoor recreation WTP values from a literature survey by Sorg and Loomis (1984).

As reported by Walsh and Gilliam, marginal costs of management per visitor day for wilderness and developed camping area are $2.75 and $2.50, respectively. For comparison purposes, most other estimates of public recreation site management costs are reported on an average rather than marginal cost basis. A review of public outdoor recreation facility costs shows the above marginal costs fall at the low end of average costs (Reiling, et al., 1983).

One comprehensive study of outdoor recreation supply and demand does report marginal costs (Daniels, 1987). Daniels finds marginal costs to be approximately $0.12 per visitor day on a developed Forest Service campsite in Montana. This marginal cost suggests that the
Walsh and Gilliam estimate of Brainard Lake management costs may not be representative of typical marginal costs on Forest Service campgrounds. Since no comprehensive marginal cost study exists for wilderness areas, Walsh and Gilliam figures are used in fee computation.

With marginal costs and WTP valuations from Walsh and Gilliam (1982), the ratios of (6.24) used to verify an equality in (6.22) are:

<table>
<thead>
<tr>
<th>WTP Ratio</th>
<th>Cm Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8.70</td>
<td>$2.50</td>
</tr>
<tr>
<td>$13.90</td>
<td>$2.75</td>
</tr>
</tbody>
</table>

Based on actual valuations and costs, an inequality in these ratios does not verify that an equality in (6.22) holds for observed resource allocations between these two public goods. However, Walsh and Gilliam research was not undertaken for purposes of allocative efficiency among public goods. Given the above use of WTP and marginal cost data differs from their original purpose, ratios of 0.63 and 0.91 probably are as close as can be expected with actual data.

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3 These estimates are on a visitor day basis. Given that both WTP and marginal cost estimates are used in ratios, visitor day is the same as summation of WTP and total Cm of one additional day of recreation use because total visitor use numbers cancel out.
Assuming present allocations of these recreational public goods give roughly equal ratios in (6.24), \( \bar{L} \) is solved for in (6.25) with wilderness data. WTP valuation for wilderness is more accurate than camping data.

\[
\bar{L} = \frac{13.90 - 2.75}{13.90} = 0.80
\]

With \( \bar{L} \) calculated from public good allocations, 0.8 is plugged into (6.23) along with previous data on \( n_{Y_kp_k} \) and \( C_{m_k} \). With average \( C_{m_k} \) data, the result is:

\[
\frac{$0.53 \text{ per AUM} - p_k}{p_k} = \frac{0.8}{-1.0632}
\]

\[(1 - 0.7524) \times p_k = $0.53 \text{ per AUM} \]

\[p_k = $2.14 \text{ per AUM}.\]

A Federal grazing fee of $2.14 per AUM is the result only if all demands for \( Y_k \) and \( Z_j \) are satisfied at this price. When these demands are met, a $2.14 fee and existing allocations among public goods both represent optimal levels based on a welfare maximization objective function with constraints (6.2) through (6.4). Using a range of \( C_{m_k} \) from Rafsnider, et al. (1983), FS grazing fee estimates range from 0.97 to 3.27 per AUM.

Since this pricing method determines \( p_k \) and \( Z_j \) (which dictates production of \( Y_k \)) simultaneously, an optimal solution method for BLM/FS bureaucrats involves an iterative process to maximize welfare.
For such an iterative process, initial allocations among public goods are determined by BLM/FS administrators to produce an equality for (6.24). With \( L \) defined from this equality, \( p_k \) is computed given elasticity and marginal cost estimates. The process iterates when demand levels for \( Y_k \) and \( Z_j \) at \( p_k \) are compared with public sector production capabilities. Under an assumption that the public sector meets all demands, unsatisfied demand in \( Y_k \) or \( Z_j \) requires Federal agency readjustment between private and public good production. Given a new level of \( Z_j \), bureaucratic reallocation among public goods occurs to equate (6.24). With \( L \) defined, the process continues until convergence occurs for \( p_k \) and \( Z_j \).

The result of this fee determination mechanism is that optimal levels of \( p_k \) and \( Y_k \) can be computed by the BLM/FS. Federal forage price and quantity that result from an iterative process are determined from the slope of permit demand functions changing price elasticity), \( C_{mk} \), and \( Z_j \) allocations (the value of \( L \)).

Without an indepth examination of the iterative process, this example shows how Federal grazing fees can be calculated. These calculations use data from: 1) Permittee demand functions for Federal forage; 2) marginal management costs of providing livestock forage; 3) allocation and valuation of public goods provided by the BLM and FS. This numerical example shows that all three data sources are available.

Ideally, fees would be determined at an individual Federal permit level with demand functions estimated for each individual permittee. Realistically, all three data sources could be gathered
at BLM District and FS National Forest levels. For permit demand functions, there are precedents for widespread collection of typical ranch data necessary to compute permit demand functions (Kehmeier, et al., 1987; Gee, et al., 1986; Gee, et al., 1985).

Major drawbacks to this proposed grazing fee mechanism include its complexity and intensive data requirements at local BLM/FS administrative levels. Administrative feasibility criteria for BLM/FS grazing fees include a fee system which is understandable to local BLM/FS administrators as well as ranchers and does not require extensive, recurring data collection (Secretary of Agriculture and the Interior, 1977). Both of these criteria are violated with the proposed grazing fee mechanism in this chapter.

The complexity of this Ramsy-Boiteux optimal pricing mechanism makes implementation especially doubtful. However, complexity of Federal forage fees is necessary if pricing of forage is to: a) Account for institutional constraints imposed by these agencies on public forage markets (allocation of permits); and b) be comparable to valuations of other resources provided by these agencies, such as outdoor recreational opportunities. There are no simple alternatives to public forage pricing under the present institutional structure.
CHAPTER VII

SUMMARY AND CONCLUSIONS

Historical data on public and private forage markets is used to show statistically significant evidence for market interdependence between these markets. Evidence comes from a case study in Harney County, Oregon. The existence of market interdependence makes pricing of public forage resources with private market data inappropriate from both a permittee use value perspective of second best pricing and "piecemeal" pricing with first best, Pareto optimal prices.

Four sections of this chapter are: 1) Summary of research; 2) research conclusions; 3) market interdependence impact on Federal grazing fee systems; and 4) research questions which remain unanswered.

Summary of Research

The purpose of this research is to test for the existence of public/private forage market interdependence. The research approach in this thesis is to test for market interdependence between the quantity of forage provided in public markets and observed private market price and quantity.

The research objectives are to establish the existence of forage market interdependence from two perspectives; 1) A theoretical framework to establish the importance of market interdependence when using the comparable markets method to price Federal forage; and 2)
testing for statistically significant evidence of market interdependence with historical data from public and private forage markets. Both of these objectives are undertaken to demonstrate the importance of market interdependence in the establishment of Federal grazing fees, specifically for Bureau of Land Management (BLM) and Forest Service (FS) managed lands.

The need to conduct research on market interdependence has developed because of the use of comparable market methods to price Federal forage resources. Both Federal markets examined in this research (BLM/FS and Malheur National Wildlife Refuge grazing programs) use data from private forage land lease markets to establish grazing fees. The existence of market interdependence presents two pricing problems for the comparable market method: 1) Violation of the fundamental appraisal principle that a resource being valued (Federal forage) does not influence market exchange values used to determine value (private lease rates); and 2) non-zero cross price elasticities between public/private markets to violate sufficient conditions for appropriate "piecemeal" pricing (Boadway and Harris, 1977). The first problem is pricing under the Theory of Second Best with an institutional constraint of Federal restrictions on market participants. The second problem involves pricing to achieve Pareto optimal, first best prices.

Model estimation and testing for interdependence are done under conditions of public livestock forage reductions. Given large changes in administratively set public forage quantities, statistically significant evidence of interdependence is assumed to
occur if the size of the public market is large compared with private forage markets. The influence on private forage market price and quantity comes from Federal grazing permittees using private market forage resources as a replacement for lost endowments of public forage.

The existence of market interdependence is shown in a case study for Harney County, Oregon. Market interdependence occurs between the Refuge grazing program and the alfalfa hay market in Harney County. An "official" policy of livestock grazing reductions occurred on the Refuge during the 1970s. Substantial reductions in Refuge forage provide an ideal opportunity to test for existence of market interdependence with historical data.

A survey of Refuge permittees reveals that the two most common ranch management responses to permit changes are improvement of deeded land and buying hay. Of the 31 ranch operations surveyed, 32 percent improved forage production on deeded land (1/4 of improved acreage was alfalfa hay production) and 26 percent bought hay.

To examine production and price influences on the alfalfa hay market because of Refuge forage reductions, two equations are estimated. Testing for statistically significant evidence of market interdependence is done at two levels: 1) T-tests to determine if Refuge forage coefficients are statistically less than zero; and 2) restriction testing for structural change in Refuge coefficients before versus after the Refuge forage reduction policy. Estimation results from 1960 to 1987 data are:
A) Hay Production Influence

**Model 3**

\[ HAA = 0.366 + 0.028 \text{ EOAA} - 0.077 \text{ RF} - 0.060 \text{ RF}^{\text{lag}} - 6.46 D1 \]

\[ N = 28 \quad \text{Adjusted } R^2 = 0.542 \quad F_{4,23} = 8.98 \]

**Model 4**

\[ HAA = 0.406 + 0.090 \text{ LAA} - 0.062 \text{ RF} - 0.057 \text{ RF}^{\text{lag}} - 6.41 D1 \]

\[ N = 28 \quad \text{Adjusted } R^2 = 0.546 \quad F_{3,24} = 9.118 \]

B) Hay Price Influence

\[ HP = 69.43 \text{ INT1} + 104.49 \text{ INT2} - 0.790 \text{ H} + 0.443 \text{ C} - 0.796 \text{ RF} \]

\[ N = 27 \quad \text{Adjusted } R^2 = 0.629 \]

where:

HAA = changes in Harney County alfalfa hay acreage;

EOAA = changes in Eastern Oregon alfalfa hay acreage;
LAA = changes in Lake County alfalfa hay acreage;

RF = absolute change in Refuge provided forage from 1974 to 1987;

D1 = dummy variable for Malheur and Harney lakes flood impact in 1983;

HP = real alfalfa hay price in Harney County;

H = alfalfa hay production in Harney County;

C = cattle numbers in Harney County.

For alfalfa hay production, Refuge forage changes influence changes in hay acreage. Two motivations are postulated for increased development of alfalfa hayland: 1) Permittees use alfalfa to replace Refuge forage to balance their operation's seasonal forage resources; and 2) anticipation of higher alfalfa hay prices in the future because of increased demand for hay leads to development of more alfalfa hayland. Models 3 and 4 are judged equally representative in explanation of variation in Harney County alfalfa hay acreage changes (HAA). These models use EOAA and LAA as proxy variables to explain changing price expectations and economic growth as factors which influence hay acreage changes.

With t-statistics in parenthesis, both RF and a lagged RF have statistically negative coefficients to explain HAA (t_{23,.05} = 1.714). In addition, RF coefficients in both models show a significant structural change after the Refuge began a reduction policy in 1973.
(F_{2,23} = 3.277 and 3.626 for Models 3 and 4, respectively). Thus, both levels of statistically significant evidence for market interdependence are found in hay production influence due to Refuge forage reductions.

With insignificant coefficients on LAA and EOAA, Models 3 and 4 show that changes in Harney County alfalfa hay acres are not explained by acreage changes in Lake County and the rest of Eastern Oregon. With significant RF coefficients in these models, Refuge forage reductions are responsible for HAA being different from hay acreage changes in other areas. The existence of market interdependence is reinforced by insignificant LAA and EOAA coefficients in Models 3 and 4.

The total estimated impact on Harney County alfalfa hay acreage is an increase of between 118 and 137 acres for every 1,000 AUM reduction in Refuge forage. These econometric estimates are about twice the size of the estimated influence from survey data (64 acres per 1,000 AUM reduction). However, these two estimates are statistically compatible based on coefficient restriction testing. If the "true" influence is between these estimates, this influence is substantial.

Estimated RF coefficient in the alfalfa hay price model is statistically negative (t_{19,.05} = 1.729). This evidence of interdependence is not reinforced by structural change testing. The RF coefficient does not show a statistically significant structural change. Only the intercept term (INT1 and INT2) is structurally

This research also includes testing for the existence of market interdependence in two other public/private forage markets: 1) BLM/FS grazing program and private grazing land lease markets; and 2) Refuge grazing program and Harney County forage land lease market. Coefficient estimation and testing do not show evidence for existence in either case. Primary reasons for non-support of interdependence are: a) No "official" policy of grazing reductions on BLM/FS public lands that was applied uniformly over the study areas (Pacific Northwest states); and b) private forage leases are not commonly substituted for Refuge forage by permittees when reductions in their Refuge permit occur.

Despite non-support for interdependence from BLM/FS forage markets, the existence of market interdependence in Harney County is comparable with BLM/FS grazing programs and their influence on Western private grazing land lease markets. Based on ratios of public to private market size, the Refuge grazing program was only slightly larger than the size of the Harney County alfalfa hay market before reductions began (ratio of 1.13). Throughout the western U.S., a ratio of BLM/FS to private lease markets of about three is much greater than 1.13. Thus, public/private forage market interdependence in Harney County provides a reasonable basis for the inference of interdependence influences on private grazing land lease markets from BLM/FS forage markets throughout the western United States.
Research Conclusions

Both Harney County alfalfa hay production and price are affected by reductions in Refuge forage. Regression equations reveal statistically significant evidence for the existence of public/private forage market interdependence. This evidence means that both pricing problems exist for Federal forage. First, the size of the Refuge forage market before the reduction policy is sufficiently large to affect hay market exchange values if markets were combined. Second, nonzero cross price/quantity elasticities exist between public and private markets.

The existence of public/private forage market interdependence has two strong implications for pricing of Federal forage using private market price data. First, under second best pricing, appropriate use value appraisal from private market exchange values requires an adjustment of observed prices for the impact from combining supply and demand from both public and private markets.

The second implication is that first best, Pareto optimal pricing by use of private market data is an inappropriate "piecemeal" pricing policy for the Refuge.\(^1\) As set forth by Boadway and Harris, sufficient conditions for first best, Pareto optimal pricing are non-zero cross-price elasticities. The non-zero cross elasticity between Federal quantity and private hay price from research results of this

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\(^1\) With market interdependence, implementation of a first best pricing policy would be appropriate only, under third best considerations (Ng, 1980). Under third best conditions, information poverty exists as to second best pricing data (i.e. permittee use values).
thesis infers that sufficient conditions are violated. This inference is based on prior research that showed a statistical relationship between public forage quantity utilized and its price (Johson and Watts, 1988). Together, the results from Johnson and Watts and this thesis imply a non-zero cross-price elasticity between private forage quantity demanded and Federal forage price (Equations (2.11) to (2.13) in Chapter II).

Estimated Refuge influence from the hay production and price models is primarily evidence of market interdependence. This information does not provide an appropriate adjustment of private market data for interdependence. An example of adequate interdependence adjustments is supply and demand modelling to assess the impact of both public forage market quantities and demanders on a private forage market exchange value. This type of adjustment is necessary to make private forage market data appropriate for second best pricing public forage resources.

Two other issues related to market interdependence also are examined in this thesis. First, bureaucratic motivation for pricing of BLM/FS forage is hypothesized in Chapter V. This motivation is postulated to be management of public land to service what they perceive is in the public interest—land resource conservation and sustainability of resource production. Motivations of land conservation are tied to forage pricing based on bureaucratic use of grazing fees to control public land livestock grazing. An increase in Federal fees justified by private market price data results in desired reductions in livestock use and thereby achieves improvements
in public rangelands. Since downward adjustments from private market price would result from consideration of market inter-dependence, BLM/FS bureaucrats ignore interdependence in establishment of Federal grazing fees. This allows Federal fees to be established as close as possible to private lease rates, which are much higher than the current Federal grazing fee.

Second, an alternative grazing fee mechanism is explored in Chapter VI. This mechanism does not use private market price data to establish grazing fees and avoids market interdependence issues. Under this mechanism, fees are set based on Ramsey-Boiteux optimal pricing conditions (Ramsey, 1927; Boiteux, 1956). Information used to price forage includes: a) Permittee demand functions for Federal forage; b) marginal costs of Federal land management; c) allocation and valuation of outdoor recreational goods provided by the BLM and FS. A numerical example is presented to show that existing data are sufficient to compute Federal grazing fees using this mechanism.

A final conclusion is drawn from the theoretical models of Federal forage pricing. This conclusion concerns the initial market structure of Federal forage markets. The initial structure, one that still applies, is one of non-price allocation of forage resources. Stemming from this second best institutional constraint, market interconnections like market interdependence create conditions for the Theory of Second Best to apply in pricing of Federal forage rather than first best, Pareto optimal pricing.
Market Interdependence Influence on Federal Grazing Fee Systems

Brokken and McCarl (1987) list three types of Federal grazing fee systems that are most successful in meeting fee evaluation criteria: 1) Fee formulas such as the one established by PRIA legislation; 2) competitive bidding; and 3) cost of administration. As applied to these alternative fee systems, the existence of market interdependence affects both the first and second. Since private market data are not involved, market interdependence has no impact on grazing fees based on administrative costs.

The market interdependence influence on fee formulas comes from a rejection of sufficient conditions for first best, Pareto optimal pricing. Implementation of first best pricing by a "piecemeal" approach is inappropriate with market interdependence. Under interdependence, this type of pricing cannot be justified on the basis of economic welfare arguments. This means that fee formulas which use first best pricing for their underlying economic assumptions are not justifiable from an economic welfare standpoint. With the presence of market interdependence, formula pricing of Federal forage with only private market price data becomes a value judgment, i.e. Federal permittees should pay what private market lessees pay is a value judgment.

An example of first best pricing is a modified market value fee system (U.S. Department of Agriculture and the Interior, 1986). Under this formula, Federal grazing fees are inferred from appraised Federal forage values based on private market grazing land lease
transactions. Federal fees are adjusted annually with an index of private lease rate changes. Market interdependence makes the modified market value fee system inappropriate to improve social welfare, because Federal grazing fees have an effect on demand for private grazing land leases.

Some Federal grazing fee formulas move away from first best pricing assumptions. These formulas adjust private market lease rate information with other considerations, like ability to pay in the PRIA formula. In these formulas, market interdependence considerations become less important because the Federal forage pricing objective is no longer strictly Pareto optimality.

As for competitive bidding, market interdependence has an impact on Federal fees because this type of fee system is a movement towards combining public and private forage markets. With the existence of market interdependence, private market characteristics are altered by this combination.

By altering market characteristics, two additional problems are introduced: 1) Private market appraised values for Federal forage pricing do not coincide with actual fees from bidding; and 2) distribution of land income between lessor and lessee is changed. Under both situations, the direction of change in exchange value is important. This change determines the distributive effects of the market interdependence impact.

As an example, a downward movement in exchange values results in competitive bids for Federal forage below those appraised values from the private market. This situation has negative consequences
when appraised values are used as minimum bids. Lower exchange values also would decrease both rental income to lessors and expenses to lessees.

The result of competitive bidding under market interdependence is impacts (both positive and negative) on private grazing land lease market participants heretofore not considered in evaluation of competitive bidding (Brokken and McCarl, 1987; U.S. Department of Agriculture and the Interior, 1986).

**Research Questions Unanswered**

This research hopefully will stimulate interest in market interdependence as an area of concern in the Federal (specifically BLM/FS) grazing fee debate and promote further research. Among remaining unanswered questions are: 1) What would be the impact on private market grazing land lease rates from a simulated combination of BLM/FS and private grazing land lease markets; and 2) is the private grazing land lease market the most common forage market substitute for BLM/FS permittees or are other forage markets more accessible to replace lost public land forage?

The first question is basically unanswered in this research. As mentioned in Chapter V, information cost concerns may dictate employment of hay price changes with Refuge quantity reductions. However, such a situation is strictly a "best information available" scenario for market interdependence adjustments. Proper interdependence adjustments require private forage market simulation.
Without historical examples, simulation of combined markets is required to obtain estimates of actual adjustments that must be made for market interdependence impacts. This type of research is needed because after a problem such as market interdependence is recognized (the purpose of this research), a solution must be made available before this problem is dealt with in the public policy arena.

The second unanswered question has been investigated hypothetically by both survey (Quigley et al., 1986; Heintz, 1981) and by typical ranch model approaches (Olsen and Jackson, 1975; Kearl, 1964; BLM, 1962). Refuge permittee survey results as reported in this thesis provide one of the few documented responses to public market forage reductions. A similar survey based on actual BLM/FS grazing reductions is warranted to investigate whether private leasing is commonly substituted from BLM/FS grazing.
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APPENDICES
APPENDIX A

SURVEY OF PAST AND PRESENT REFUGE PERMITTEES

MAY 1988
Appendix A
Survey of Past and Present Refuge Permittees
May 1988

These questions relate to how Refuge permittee livestock operations in Harney County responded to cutbacks in authorized grazing on the Malheur National Wildlife Refuge. Most cutbacks occurred between 1972 to the early 1980s. Please help us in our research by answering these questions to the best of your ability. All information is strictly confidential.

Interviewee ___________________ Date _____________

PART I - Your Present Operation

A) What type of ranch operation do you presently operate?
   a) cow-calf
   b) cow-yearling
   c) combination of a) & b)
   d) stocker
   e) sheep

B) How many head of breeding stock do you presently run? (with stocker, give total number of head)
   less than 100
   100 to 250
   251 to 500
   501 to 1,000
   over 1,000

C) Do you have a season where you presently tend to run short of feed during normal years? If yes, which one and how do you solve this problem?

PART II
This part goes back to your operation during the 1970s or 1980s before and then after your permit cutback/cancellation. Please answer these questions to the best that your memory can recall.

Refuge records show the following cutbacks/cancellation of actual use on your operation.

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A) What type of ranch did you operate prior to use reduction?
   a) cow-calf
   b) cow-yearling
   c) combination of a) and b)
   d) stocker
   e) other

B) Approximate size of operation in breeding stock? (if stocker operation, just give total number of head)
   - less than 100
   - 100 to 250
   - 251 to 500
   - 501 to 1,000
   - over 1,000

C) Other characteristics of ranch at this time (expanding/declining herd, purchasing more property, just starting out, etc.)

D) Were there other major events happening during the above time to your operation (selling out, death in family, etc.)?

E) If you continued your operation with your deeded land and lease resources at that time, what was your first management
response, given these feed sources, to not being able to use your Refuge permit(s) either completely or partially.

a) Reduce herd size
   By how much?

Did you lease out other land in response to herd reduction? What type of land?

b) Ranch improvement on deeded land
   to increase feed supply and
   maintain herd size
   What improvements?

c) Lease private rangeland,
   irrigated pasture or hayland
   to replace lost feed
   How many acres and what kind of land?

d) Increase stocking on deeded land
   to maintain herd size

e) buy hay
   For how many years?

f) buy land

g) no change was required in
   livestock operation
   (excess feed existed)

h) change seasonal use pattern
   of operation to adjust
   What was the change?

i) other

F) Did your response change in subsequent years from your initial response; what was it and how long did it last?
Action(s):

Done when and for how long?

G) Other options are listed in part E), do you remember why none of them were chosen?

Part a)

Part b)

Part c) Why not Lease?

Part d)

Part e)

Part f)

Part g)

Part h)

H) Did the cutback/cancellation of Refuge permit result in any other problems with your ranch operation - such as profitable size of operation, couldn't afford other sources of forage to replace Refuge permit, unbalanced nature of operation made unaffordable as one unit?
APPENDIX B

DATA USED IN ESTIMATION OF MODELS B AND C
Appendix B. Data Used in Estimation of Models B and C.

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<th>Year</th>
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Appendix B. Data Used in Estimation of Models B and C (continued)

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