AN ABSTRACT OF THE THESIS OF

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K. Norman Johnson

Recent changes in public timber supplies in the Pacific Northwest have increased the importance of the role private timber plays in the forest products industry and local communities. Most economic models of timber supply, however, have emphasized national or regional markets where data are adequate and statistical testing methodologies relatively well documented. Little attention has been paid to modeling timber harvests at the local market level. This study attempts to develop an economic model to explain timber harvests at the county level where previous efforts, which have emphasized a simultaneous equations approach, have met with poor results.

A set of economic timber harvest relations was tested for eight counties in Northwest Oregon using the seemingly unrelated regressions (SUR) technique. For industrial landowners, a present net worth maximization model was used where harvest is a function of stumpage price, discount rate, and level of growing stock inventory. For non-industrial private landowners a utility maximization model was used where harvest is a function of

stumpage price, personal income, and level of growing stock inventory. Parameter coefficient estimates developed using SUR were compared with those developed using ordinary least squares (OLS) to evaluate the adequacy of the error-related approach.

Results of the study showed significant contemporaneous correlation between harvests in the counties of the study region for both industrial and non-industrial landowners. Therefore parameter coefficient estimates obtained using SUR are more efficient than those obtained with OLS. The greatest improvements in modeling efficiency were observed for non-industrial owners. Furthermore, the present net worth maximization model used for industrial landowners appears to reasonably represent the harvest motivations of those landowners. However, the high standard errors and poor explanatory power observed in the non-industrial landowner estimations suggest that the utility maximization model used for those landowners needs to be re-evaluated.

For both landowners, the level of growing stock inventory plays a large role in determining timber harvests. Policy makers and analysts interested in predicting county-level timber harvests should advocate the collection of more extensive county-level inventory information than is currently collected. The recording of county-specific price information would also prove valuable for future analyses by eliminating the need for a proxy variable.

Modeling Local Timber Harvests Using a Set of Error-Related Economic Relations

by

Trevor M. Stone

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Trevor M. Stone, Author

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Modeling Local Timber Harvest Using a Set of Error-Related Economic Relations

Introduction

Several economic models have been developed and tested to explain private timber harvests (Robinson, 1974; Adams and Haynes, 1980; Braanlund et al., 1985). Most of these models have utilized aggregate data from large geographic areas and markets. Little attention however has been paid to modeling timber harvest and supply at the local market level. As a result, there is a considerable body of valuable knowledge with which the impacts of changing economic conditions, forest policies, or forest conditions can be assessed at the national or regional levels. At the local market level, however, there is limited information that can be used to evaluate how changes in these variables will influence local harvest and supply.

From a theoretical standpoint, modeling timber harvest and supply for small market areas presents a unique problem, one aspect of which involves the development of appropriate theoretical models for modeling harvests at the local level. For example, are theoretical models that have proven appropriate for large geographic market areas also appropriate for small areas? Or is further research needed with regard to local timber supply theory? A second aspect of the problem concerns developing appropriate statistical techniques for testing models of local markets. That is, the question arises as to whether ordinary least squares, used routinely in econometric modeling, will perform equally as well with local market data as it does with aggregate data. Or are there other statistical techniques that will provide more precise estimates of timber harvest/supply at the local market level? This study concerns itself primarily with the latter of these two aspects of the local market modeling problem. In particular, this study places emphasis on developing a single-equation statistical model for explaining and projecting timber harvest at the local market level.

From an applied standpoint, developing accurate estimates of timber harvest at the local level has several potential advantages. First, developing accurate estimates of local economic timber supply relationships can provide valuable information for timber-dependent communities which rely on the forest products industry for employment, payroll and community stability. Secondly, knowledge of local timber markets provides forest managers with specific information about stumpage prices, landowner harvesting behavior, and other variables that influence local supply and demand relationships for timber. Finally, developing local harvest and supply relationships can provide policy makers and analysts with the tools needed to accurately assess how changes in forest policies will affect local timber harvests.

Modeling timber supply for small regions poses several difficulties that are typically more troublesome than when dealing with aggregate regional or national market levels. In some regions, markets for private stumpage are poorly defined due to the presence of public stumpage supplies, monopsonistic or oligopsonistic conditions, or the lack of market information on the part of sellers. In many cases modeling timber supply at the local level is also characterized by a lack of adequate data that are specific to local market conditions.

Purpose of Current Study

The purpose of the present study is to develop a model of private timber harvest for a local market in Western Oregon using a set of error-related economic relations. For individual counties in the region separate theoretical models are specified for both industrial and non-industrial landowners. The corresponding statistical models for each landowner are then pooled across counties and analyzed using seemingly unrelated regressions (SUR). The parameter estimates developed using SUR are then compared to OLS estimates to evaluate the adequacy of the error related approach. This approach makes use of the premise that timber harvests in counties with similar forest and economic conditions may be contemporaneously correlated. Thus models which incorporate a contemporaneously correlated error structure may provide more precise estimates of relationships which determine local timber harvest and supply than models that do not incorporate a contemporaneously correlated error structure. This study is designed to provide a foundation for further methodology and data analysis research for modeling timber supply at the local market level.

Scope of the Current Study: Spatial Disaggregation

The use of data disaggregated to the county level has been used in several studies concerning timber availability, that is, studies which develop potential harvests based on the long-term development of growing stock inventories under various management assumptions. However, the use of county-level data has seen limited use in the development of stochastic economic relationships concerning timber harvest and supply. This is likely due to several factors including the lack of adequate county-level data for many of the variables thought to influence timber harvest and supply and a general emphasis within the research community on developing aggregate timber harvest and supply relationships.

Defining a county as a local market area has several practical advantages. First, many of the variables thought to influence timber harvest such as land ownership, income, growing stock inventory, and many demographic variables are reported by county. Thus, the county provides a convenient economic unit when adequate data are scarce. Secondly, forest conditions such as species types, historical disturbance patterns, and forestry practices are likely to be similar within a given county. Finally, landowners within a given county are likely to be subject to similar demand forces, merchantability standards, and production costs.

Scope of the Current Study: Spatial Description

The present study utilizes historical time series data for 8 counties in northwestern Oregon (Figure 1).

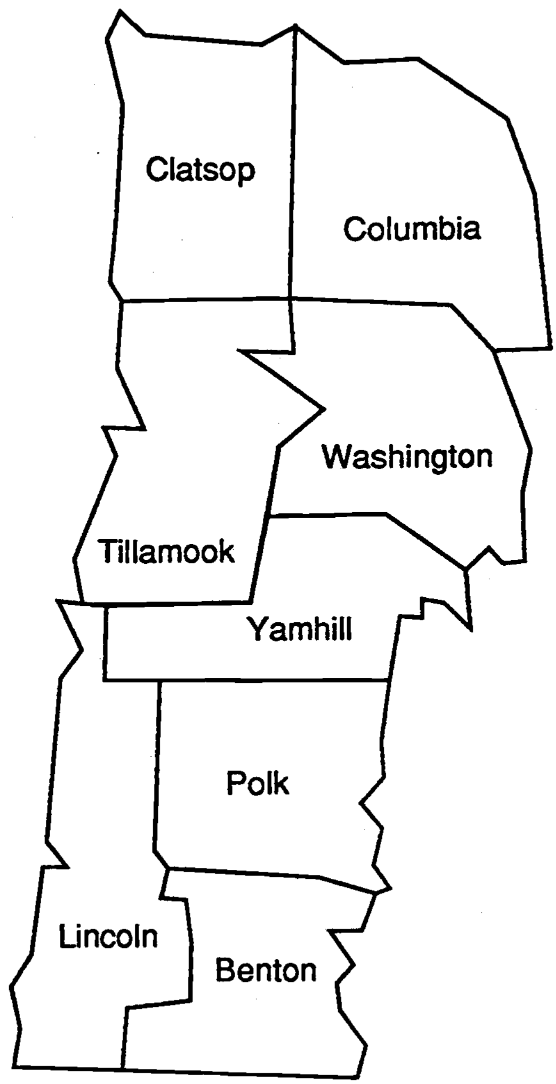


Figure 1. Study Area Map

The region occupies approximately 4 million acres, 70% of which are classified as forest land (Table 1.). The region extends southward from the Columbia River to the approximate mid-point of the Coast Range Mountains and is bordered on the West by the Pacific Ocean and on the East by the Willamette Valley. The area has historically been a major timber producing center of the Pacific Northwest.

Table 1. Timberland/Land Area: Oregon North Coast Counties

County	Timberland Area (thousand acres)	Total Land Area (thousand acres)
Benton	265	428
Clatsop	415	515
Columbia	305	408
Lincoln	553	631
Polk	254	471
Tillamook	606	713
Washington	234	465
Yamhill	240	455

Source: Gedney (1982)

Timberland ownership in the study area is dominated by industrial landowners who own approximately 1.1 million acres. Non-industrial landowners in the region are the second largest landholders with approximately 680,000 acres. The predominant public timberland owner in the region is the Other Public sector with 542,000 acres. This ownership consists primarily of the Tillamook State Forest in Tillamook County and some county and local government land. Additional public forest land owners include the federal government with approximately 256,000 acres managed by the US Forest Service (USFS) and 227,000 acres managed by the Bureau of Land Management (BLM). In aggregate, 63% of the forest land in the region is owned by private landowners and the remaining 37% is owned by public owners (Figure 1.).

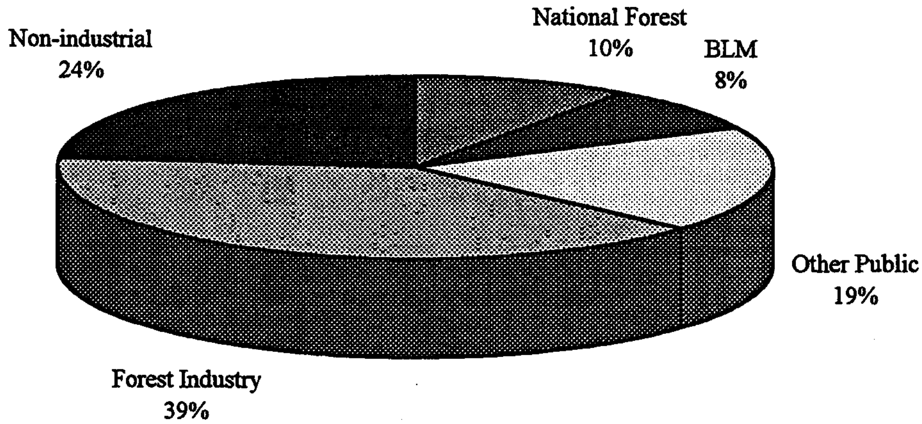


Figure 2. Land Ownership: Oregon North Coast Counties
Source: Gedney (1982)

The abundance of private land in the study region is unique within the State of Oregon and has gained particular significance in light of current forest policy changes for public lands which are expected to reduce timber supplies from those lands. Historical harvesting and forest disturbance patterns on both private and public lands in the study region have created numerous stands which are expected to reach harvest age in the near future. As a result, the region is generally regarded as being the source of much of Oregon's economically available timber supply in the near future (Sessions et al., 1990).

Scope of the Current Study: Historical Harvesting Patterns

For the period 1968 to 1993, total timber harvest volume in the study region ranged from a low of 973 MMBF (Scribner Log Rule) in 1982 to a high of 1,735 MMBF in 1986

(Figure 3.). The average volume of combined total harvest for both public and private landowners for the period was 1,319 MMBF.

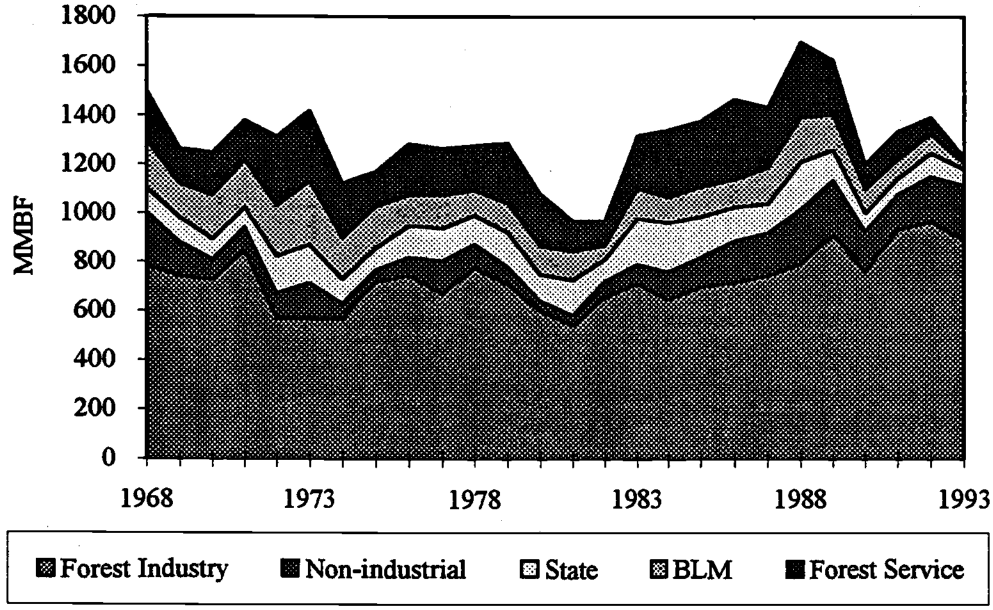


Figure 3. Historic Timber Harvest: Oregon North Coast Counties

Industrial timber harvests in the region have historically exceeded those of other landowners. This trend reflects both the preponderance of industrial lands as well as an historically viable forest products industry in the region. Harvests for industrial landowners in the region averaged 730 MMBF for the period 1968 to 1993 with a peak harvest in 1992 at 964 MMBF and a low in 1981 at 542 MMBF. For other landowners in the region, the USFS average harvest levels were greatest (195 MMBF) followed by the BLM, non-industrial landowners, and the State of Oregon, respectively. The combined average annual harvest of 854 MMBF from industrial and non-industrial private lands in the North Coast counties represents approximately 29% of the annual harvest for private lands in all of western Oregon for the period 1968 - 1993.

Variability in annual harvest volumes from the various landowners is illustrative of the motivations of the various landowners for owning and managing timberland in the region (Table 2.).

Table 2. Annual Harvest Statistics, Oregon North Coast Counties: 1968-1993

Ownership	Average Harvest (MBF)	Coefficient of Variation	Maximum Harvest (Year)	Minimum Harvest (Year)
Forest Industry	730,444	16%	964,448 (1992)	542,327 (1981)
Non-industrial	123,617	48%	224,501 (1989)	39,919 (1980)
State	121,859	32%	200,427 (1984)	67,238 (1991)
BLM	134,719	38%	258,482 (1973)	25,942 (1993)
Forest Service	194,749	40%	328,400 (1986)	21,927 (1993)

Source: Oregon Department of Forestry Annual Harvest Reports

Industrial landowners, whose lands are intensively managed, and whose management actions are financially motivated, have historically exhibited the least year to year variability in annual harvest volume. Non-industrial landowners, whose management goals tend to be motivated by both financial and non-financial goals, have exhibited the greatest year to year variability. Among public owners, State harvests, which are based primarily on financial criteria and harvest flow considerations, exhibit the least variability followed by the federal landowners whose harvest levels are largely established without regard to economic considerations.

Scope of the Current Study: Regional Processing Sector

Timber suppliers in the study area are subject to demand forces from within the eight county study area and from the greater Western Oregon region. Mill survey data from Manock et al., (1970), Howard and Hiserote (1978), Howard and Ward (1985), and Howard and Ward (1991) identify six primary market sectors for the region's timber supply: lumber, veneer and plywood, pulp and board, shake and shingle, export, and post, pole, and piling. The dominant industry sector in the Western Oregon region and the North Coast market area is the lumber industry which annually processes between 60% and 80% of the logs processed in the region and market area (Figure 4.). Other major users of the region's timber supply are the plywood and veneer industry and the export market.

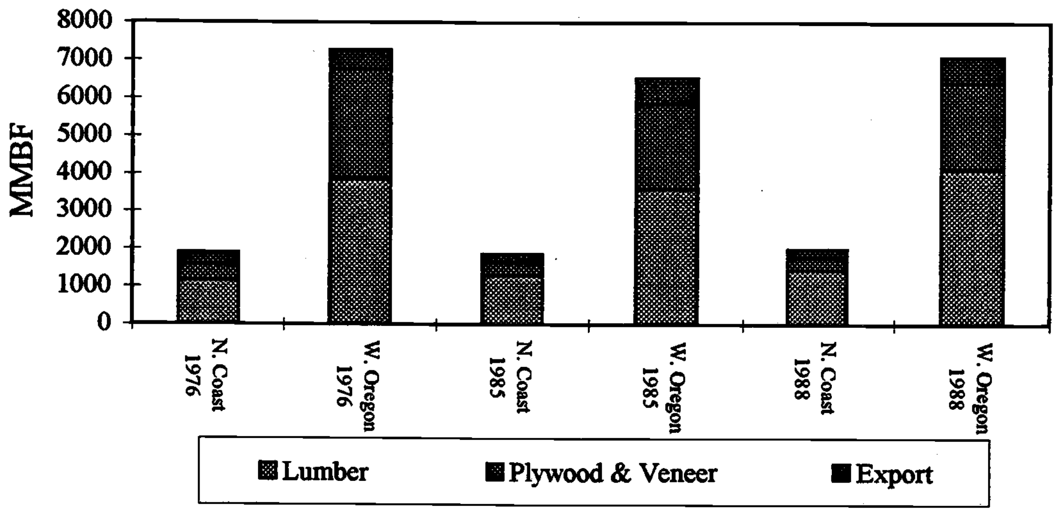


Figure 4. Local and Regional Log Use by Industry

Figure 4 also demonstrates the relative proportion of processed volume contributed to the Western Oregon total by the North Coast market area. For each of the years the adequate data are available, processed volume in the North Coast has been approximately 25% of the total volume processed in Western Oregon.

Review of Relevant Research

Harvesting Behavior

Private timber supply for a given region can be thought of as the aggregation of the various suppliers' marginal cost curves for that region (Jackson, 1980); (Gregory, 1987). An individual supplier's contribution to the regional timber supply is thus a function of their real, and sometimes perceived, marginal costs per acre of timberland. Classical capital asset theory in forestry treats these costs as those associated with allocation of capital over time. Duerr and Bond (1952) applied a marginal approach to capital allocation to determine the optimal stocking level for an uneven aged timber stand, and Duerr (1960) used a marginal approach to determine the optimal rotation for an even aged forest. This work treated the marginal costs as a combination of biological, growth-determined factors and economic factors that determine the optimal rotation and stocking level. Thus the quantity that suppliers are willing to supply at given prices over time in a given region is tied closely to inventory levels, stumpage prices, non-timber values, and other factors.

The factors which influence a firm's, or an individual's, marginal cost curve and therefore their harvesting behavior, can vary widely however. Gedney (1983) showed that there were significant differences between landowners in western Oregon in their harvesting rates and methods. Industrial landowners were found to have the highest proportion of manageable forests and a high rate of clear cutting. Farmers were found to have a low proportion of manageable forests and a high rate of clearcutting, while individuals other than farmers had a low rate of clearcutting and ranked between the other two groups in the proportion of manageable forest land. In an analysis of harvesting behavior in western Oregon, Connaughton and Campbell (1991) attribute these differences in the probability of harvest among landowners to stand conditions, such as volume per acre and growth rate, rather than land ownership class. This appears to contradict the findings of Adams and Haynes (1990) who point out that a decline in non-industrial harvest occurred in the three decades prior to 1980 despite rising inventories and prices. Lettman and McKay (1994) found that the relationship between stand conditions and probability of harvest also held for eastern Oregon, but, because of different species types and management practices, the relationships held at the tree level rather than at the stand level. Lettman et al. (1991) also showed a recent upward trend in clearcutting among both industrial and non-industrial landowners. Wear and Flamm (1993) who determined harvest probabilities for public and private lands in the southern Appalachian region using spatial data from satellite imagery, and found a higher probability of harvest, after accounting for site factors, on private lands than on public lands.

These studies suggest that for private landowners the factors that determine timber harvesting rates are those factors associated with stand value such as growing stock inventory, stumpage prices, and discount rates. This supports the models put forth by Duerr and Bond (1952) and Duerr (1960). However, additional evidence suggests that for non-industrial landowners harvests are also influenced by other factors. Cleaves and

Bennett (1995) report higher rates of harvest participation for non-industrial landowners in western Oregon with larger ownership sizes, longer tenure, corporate organization, farm ownership, and higher personal income.

Timber Supply Models

Models of timber supply can generally be classified into one of two categories based on the length of run: long-run models which are deterministic in nature, and short-run stochastic models (Binkley, 1987). The distinction is not always clear however. Many long term analyses incorporate short run supply models, and most short run models include variables which link them to the long run.

Long-Run Models

The issue of long term timber supply has been a concern for some time and in fact was the impetus for creation of the National Forest system in the early part of the twentieth century (Davis and Johnson, 1987). Generally, long-run models of timber supply examine timber supply from the standpoint of steady state conditions where prices and costs are known and the time period is adequate for economically optimal conditions to be achieved. In long-run analyses, the supply is not constrained by the current inventory and the problem is one of determining the supply given the specified steady state inventory conditions. In effect, long-run timber supply analyses are not economic models in that they do not assess the true economic supply, but rather the economically available supply under a set of possible management objectives and forest practices. Most long-run supply models emphasize two primary variables: the yields per unit area of forest land, and the area of forest land in production.

Due to their emphasis on management and growth and yield rather than economic factors, some long-run supply analyses are best referred to as "timber availability" studies rather than supply studies. Two such studies conducted for the State of Oregon by Beuter et al. (1976) and Sessions et al. (1990) incorporated various management scenarios that affected either timber yields per acre or the number of acres in production. Beuter et al., for example, developed yield projections using seven different levels of management intensity and two different harvest control specifications. Additionally, the models used in the study included assumptions about land use shifts, regeneration practices, species conversion, harvesting practices, timber utilization standards, and future growth. In an update of the Beuter et al. study, Sessions et al. (1990) assigned management intensities to specific landowners in an effort to develop more accurate harvest projections. Management intensities on private industrial lands were assigned on a percentage basis using survey data of managers' intentions, and for private non-industrial lands using survey data of forest practices and service foresters. This study also incorporated growth and yield models to project forest yields in addition to including assumptions used in the Beuter et al. study.

A similar approach was taken by Adams et al. (1992) in an assessment of Western Washington's timber supply. In this study, inventory projections for private lands were made using possible land use changes and various management intensities. Harvests were then projected using strict even flow, sequential look ahead even flow, and an econometric supply projection. Separate econometric models were developed for industrial and non-industrial landowners based on variables thought to influence harvest behavior. Harvests for public owners were projected directly from forest plans for the National Forests and by strict even flow and sequential look ahead even flow for state lands.

Other long-run timber supply analyses have attempted to incorporate economic constraints such as production costs, stumpage prices, and demand estimates in an attempt to estimate true economic supply. In an analysis of the forest land area needed to meet future timber demands in California, Vaux (1973) used yields per acre for five site classes and four forest types, the area in each site class/forest type, and long run production costs to estimate future supply. The study estimated a supply curve based on explicit production costs such as site preparation, planting, precommercial thinning, annual management costs and sale administration. A demand curve was also estimated using data on prospective population and income growth in the state. This demand curve illustrates one of the difficulties of incorporating economic constraints into long-run supply analyses in that the study assumed unit elasticity (-1.0) of demand. The author justifies this assumption by pointing out that any rational movement of the demand curve towards inelasticity would lead to an equilibrium quantity level of timber production above any level previously achieved in the State of California. Nevertheless, this assumption illustrates one of the potential shortcomings of trying to bridge the gap between economically available long-run timber supply and true economic long-run timber supply. That is, because all factors of production are variable in the long run, assumptions must be made for all of the steady state conditions.

In a study of long-run timber supply in the Southeastern United States, Robinson (1981) estimated a supply function using twenty economic supply price levels which were computed using stumpage price indexes, explicit management costs, and opportunity costs such as land rent and capital holding costs. The study then determined the true economic supply by applying a management plan that maximized present net worth for given acreages defined by landowner, site class, forest type, and geographic region. A demand function was included which incorporated a shift in demand which doubled the current level of consumption at current prices. Here a demand elasticity from Robinson (1974) of -0.5 was used. Despite these efforts to estimate true economic supply, the authors note that the model only represents an "upper bound" of the timber supply for the region if landowners had unlimited resources for growing timber and if timber growing were the primary objective of the landowners.

In summary, because all factors of production are variable in the long run, incorporating economic constraints into models of long-run timber supply is difficult. While providing valuable information, the resulting supply information from these models should be considered in light of the assumptions used in the models, and be viewed as an economically available supply rather than as a true economic supply. Perhaps the most valuable of the long run models are those that do not attempt to estimate the true economic supply at all. Such "timber availability" models as the Beuter et al., Sessions et al., and Adams et al. studies have considerable value due to their emphasis on the results of management intensification, growth and yield, and harvest scheduling.

Short Run Models

Short-run timber supply models attempt to explain timber supply based on prices, current inventory levels, and other factors which are thought to influence supply without regarding the long-run development of the inventory. These models inherently recognize what Duerr (1960) recognized: that timber supply is dependent on both long run inventory management and managers' reactions to price fluctuations, non-timber values, and other factors in the short term. Most of these models have taken the general form:

$$Q_t = f(P_t, I_t, Z_t)$$

Where (Q_t) is the harvest volume in period (t), (p_t) is the stumpage price in period (t), (I_t) is the level of inventory in period (t), and (Z_t) is representative of other factors which influence supply in period (t) (Binkley, 1987). Many models, particularly those of industrial supply, use only price (p_t) and inventory (I_t) to estimate supply. Other models, including many of non-industrial supply, use a host of variables under (Z_t) to estimate supply. These latter models, while difficult to develop on a large scale, are potentially the most valuable considering the number of factors which could influence supply. For example in the case of industrial owners, the need to supply processing facilities or the need to retire debt could play a significant role in determining short term timber supply. For non-industrial owners, levels of non-timber income, landowner tenure, or non-timber values may figure significantly in short term timber supply.

The Timber Assessment Market Model (TAMM) developed by Adams and Haynes (1980) analyzes stumpage supply and demand within a larger forest sector model for the United States. The model recognizes nine stumpage and forest product supply regions. Derived demand for stumpage and stumpage supply interact in a given supply/demand region to determine the price level and annual harvest. Derived demand in the model was composed of the sum of roundwood requirements for lumber, plywood, pulp products, fuelwood, log exports, and miscellaneous wood products. Short run supply functions in the models were estimated using stumpage price and inventory as independent variables. This choice of variables reflects the assumptions of the model: that landowners would vary their harvest directly with stumpage price, and that harvest will increase as inventory increases. The model worked reasonably well for forest industry ownerships; results showed expected signs on coefficients in all regions except the Pacific Southwest region. For non-industrial landowners, the model performed poorly except for two regions in the South. The authors felt that this was a result of well-developed markets for non-industrial stumpage in those regions, and poorly developed markets, readily available public stumpage, and integrated industrial ownerships in other regions. This same approach to modeling timber supply was taken by Lange (1983) in an integrated model of hardwood markets. Here estimates of the supply equations met with poor results. Five of the eight estimated equations had unexpected signs and final forms had to be fitted with constrained variables.

Other studies have taken a similar approach to modeling short-run supply. Adams (1977) estimated supply equations using price and inventory variables in a study of National

Forest harvest levels on forest product markets, and Adams et al. (1982) utilized the same supply equations within an integrated long-run model to predict the supply effects of private landowner investment. Robinson (1974) also estimated supply functions for the Douglas-fir region using stumpage price, but used an interest rate variable rather than inventory as a second independent variable representing the opportunity costs of holding timber.

Other supply analyses have recognized the dual product nature of timber supply, particularly the interaction of sawtimber and pulpwood markets. In an analysis of the Southern softwood market, Newman (1987) developed supply functions using inventory levels and both sawtimber and pulpwood stumpage prices. A similar approach was taken by Brannlund (1985) in an analysis of sawtimber and pulpwood supply in Sweden. Brannlund estimated supply functions for sawtimber using pulpwood prices, sawtimber prices, and harvesting costs. Pulpwood supply was estimated by including price expectations into the model. Sawtimber demand was estimated using lagged supply of sawtimber, the ability to pay for sawtimber, and sawtimber prices.

Several attempts have been made to incorporate demographic or non-economic variables into timber supply estimates. One recent attempt by Tuazon (1992) incorporated variables such as landowner age, personal income, and population density in addition to price and inventory in an attempt to model non-industrial timber supply in California.

As mentioned in the previous section, Adams et al. (1992) incorporated econometric models of short run timber supply for both non-industrial and industrial landowners. The industrial supply estimate was based on the theory that industrial landowners are present net worth maximizers and harvest was thus dependent upon price, inventory, and interest rate. The non-industrial model incorporated a personal income variable rather than an interest rate variable on the premise that non-industrial landowners are utility maximizers rather than present net worth maximizers.

A summary of the variables used in various studies of economic timber harvest and supply, and an indication of the scope of the studies, is presented in Table 3. For supply, variables often used are stumpage prices, growing stock inventory, and a discount rate. For demand, stumpage prices, lumber prices, and the costs of labor and capital are often used in estimation of those relationships.

Table 3. Timber Supply Studies: Summary Table

Study	Scope	Supply Variables	Demand Variables	Ownership(s)
Robinson (1974)	Southern US : southern pine stumpage Douglas-fir Region US : Douglas-fir stumpage	Southern Pine: lumber production, chip production, time trend Douglas-fir: stumpage price, interest rate		Aggregate
Adams (1977)	3 US Regions	Price, inventory	Regional product input requirements	Private
Adams and Haynes (1980)	8 US Regions	Price, inventory	Regional product input requirements	Forest Industry, Other Private
Adams et al (1982)	US	Price, inventory	Regional product input requirements	Industrial, Non-industrial
Braanlund et al (1985)	Sweden: sawtimber and pulpwood	Sawtimber: sawtimber price, pulpwood price, harvesting cost Pulpwood: lagged sawtimber supply, harvesting cost, lagged pulpwood price, sawtimber price, pulpwood price	Sawtimber: sawtimber price, ability to pay for sawtimber, lagged sawtimber supply	Aggregate
Daniels and Hyde (1986)	North Carolina: softwood and hardwood stumpage	Stumpage price, inventory	Stumpage price, final goods price	Aggregate
Newman (1987)	Southern US : pulpwood stumpage, solidwood stumpage	Pulpwood: pulpwood price, inventory, solidwood price Solidwood: solidwood price, inventory, pulpwood price	Pulpwood: pulpwood price, final goods price, wages, cost of capital, lagged pulpwood supply Solidwood: solidwood price, final product price, wages, cost of capital, lagged solidwood supply	Aggregate
Adams et al (1992)	Western Washington	Industrial: stumpage price, interest rate, inventory Non-industrial: price, per capita income		Industrial and Non-industrial
Tuazon (1992)	California	Stumpage price, inventory, personal income, landowner age, population	stumpage price, wages, lumber production	Non-industrial

Model Scale

Typical econometric timber supply analyses are conducted on a large spatial scale due to the availability of aggregate data and an interest in developing supply relations for large market areas. The previously cited studies by Adams (1977), Adams and Haynes (1980), Brannlund et al. (1985), Lange (1983) and Robinson (1974) were done at the national market level. Other analyses such as Newman (1987) and Adams et al. (1992) have been done at the regional level. Recently, interest has developed in conducting timber supply analyses at the sub-regional level in order to more accurately assess local supply and demand conditions. Jackson (1983) notes that estimating supply and demand equations using direct econometric estimation approaches is more viable than had previously been thought for small market areas. An econometric timber supply model developed by Daniels and Hyde (1986) for the State of North Carolina successfully used Jackson's approach to simultaneously estimate supply and demand equations for that State.

Few studies however have explicitly attempted to estimate economic supply functions for local markets smaller than the State or half-State level. One attempt was the Tuazon study (1992) which utilized county level data and a simultaneous equations approach to estimate non-industrial timber supply in California. Results of the study showed expected signs on all variables. However, the model's low R^2 value of .17 indicates that a significant amount of variability in non-industrial timber harvest was not explained by the model. Tuazon also utilized a single equation approach and seemingly unrelated regressions and found higher explanatory power than with the simultaneous equations approach.

Another study by Buongiorno et al. (1988) utilized time series methods to evaluate the effects of macro-economic variables on harvests in five counties in Southwestern Oregon. This study suggests that local harvests could be forecast using forecast values for macro-economic variables such as housing starts and national lumber prices. Additionally, Connaughton and Campbell (1991) developed harvest probabilities for industrial and non-industrial landowners using county level data for Western Oregon. It is conceivable that their results could be used to forecast harvests for a local market area based on stand conditions such as stand value and growth rates.

Several studies have developed non-economic timber harvest projections for local markets. The studies by Beuter et al. (1976) and Sessions et al. (1990) for example projected timber availability for multiple-county timbersheds in the State of Oregon. These studies however have the limitations discussed earlier regarding their lack of economic assumptions and reliance on stand projections and growth and yield models.

The lack of economic timber harvest/supply modeling efforts at the local market level may be due to several factors including the practical difficulty of obtaining adequate data with which to test statistical models, or a lack of knowledge concerning harvesting behavior at the local level upon which theoretical models can be based. It is also likely that policy and research activities have historically emphasized the development of aggregate timber supply models rather than local market models.

Recent interest however has developed with regard to the effects of changes in timber supplies on local economies, particularly in the Western United States where federal timber harvests have been restricted due to threatened and endangered species protection and other environmental concerns. This interest from the policy arena, combined with a general lack of information about the structure of local timber markets suggests that modeling efforts should be made at the local market level.

Methodology

The following section describes procedures used to estimate private timber supply for the eight county study region. Included are details of the specification of a theoretical model, a description of data sources for variables, and a description of model estimation and testing procedures.

Modeling Approach

Most studies of private timber supply at the regional or national level use a systems of simultaneous equations approach where statistical relationships among the variables are determined jointly (Adams and Haynes, 1980); (Tuazon, 1992); (Brannlund, 1985). Such systems are usually in the form of:

$$y_t^d = f_1(P_t)$$

$$y_t^s = f_2(P_t)$$

Where equilibrium in the model is defined as the price (P_t) where $y_t^d = y_t^s$ when y_t^d is the quantity of timber demanded and y_t^s is the quantity supplied. This approach assumes that price or any other regressor and the error term in any given period are non-independent.

An alternative approach, and the one utilized in this study, is to model timber supply as a single equation where regressors and errors are assumed to be independent. Specifying a single equation for each county in the study region, and then statistically estimating the equations using a related error structure, allows the development of local timber supply relationships without the voluminous data requirements of simultaneous equations approaches. Additionally, the single equation approach eliminates the need to specify a demand function for the local market area. Due to these factors however, the single equation approach does have the disadvantage of not recognizing the dynamic, integrated nature of timber supply relationships. That is, a single equation model does not recognize the feedback mechanism between the endogenous variable (harvest) on the left hand side of the equation, and the exogenous variables on the right hand side of the equation.

Because timber suppliers at the local market level are often price takers, that is, price is determined exogenously and timber suppliers are subject to a perfectly elastic demand curve, the assumption of independence between price and errors is not likely to be violated for local markets. For the north coast counties, where demand for timber is a function of factors outside the region, this assumption is supported by the integrated nature of many industrial landowners, the presence of a viable export market, and proximity to major wood processing centers in the Willamette Valley.

Thus the single equation approach utilized in the current study, where price is exogenously determined, is intended to be a "best compromise" approach to modeling local market conditions. That is, the single equation approach allows the estimation of a supply function for a local market area with a limited supply of data. The trade-off, however, is that price must be assumed to be exogenously determined and the dynamic relationship between supply and demand cannot be determined.

Theoretical Model Specification: Industrial Landowners

The specified models for the present study utilize the same approach used by Adams et al. (1992) where industrial landowners are assumed to be present net worth maximizers and non-industrial landowners are assumed to be utility maximizers. For industrial landowners, the factors which drive harvest are those recognized in classical forest economic theory where harvest is a function of price, inventory, and the effective discount rate. Davis and Johnson (1987) express the harvest decision under financial objectives as:

$$PNW = \max_n \left[\frac{SV_n}{(1+I)^n} + \frac{MSEV}{(1+I)^n} \right]$$

Where: Sv_n = stumpage value (price * inventory), year n

MSEV = maximum soil expectation value across all possible rotation lengths

I = discount rate

n = potential harvest year

Under these criteria the level of timber harvest is dependent upon the combination of price and quantity of timber available for harvest subject to the effective discount rate. An expectation of higher prices in the future, relative to current prices, would lead to a lower harvest level in the current period. In other words, the harvest in any given period is dependent on current prices and low current prices result in low current harvest and high current prices result in high current harvests. A similar relationship is expected for inventory as high current levels of growing stock lead to a high current level of harvest. An increase in the effective discount rate in any given period would lead to an increase in harvest due to the higher capital holding costs associated with higher discount rates.

For industrial landowners in the north coast counties, the theoretical model was specified as:

$$Y_{1t} = f(I_{1t}, P_{1t}, D_{1t})$$

Expressed statistically the model is:

$$Y_{1t} = \beta_{1t} + I_{1t}\beta_{12} + P_{1t}\beta_{13} + D_{1t}\beta_{14} + \ell_{1t}$$

Where:
Y_{1t} = Harvest in county 1, year t
I_{1t} = Industrial growing stock inventory, in county 1, year t
P_{1t} = Stumpage price in county 1, year t
D_{1t} = Discount rate in county 1, year t
e_{1t} = Disturbance term for county 1, year t
β_{1I} = parameters to be estimated for county 1, year t

Theoretical Model Specification: Non-industrial Landowners

For non-industrial landowners, the factors which drive timber harvest are described by a general form utility maximization function as described by Binkley (1987):

$$\max \int_0^{\infty} u(R, y)$$

Where $u(R,y)$ is a utility maximization function with R being non-timber outputs and y being income. Landowners are subject to income constraints and the level of growing stock inventory provides utility. In such cases, harvests are dependent on price, growing stock inventory, and income from non-timber sources. Binkley notes that the effect of income leads to three primary results: 1) supply is greater at lower levels of income, 2) increases in fixed costs such as taxes, lead to greater harvest levels, and 3) a reduction in wage rates leads to greater harvest levels. In the present study, wages and fixed costs are assumed to be constant and annual per capita income is introduced as an independent variable.

For non-industrial landowners in the north coast counties, the theoretical model is specified as:

$$Y_{1t} = (I_{1t}, P_{1t}, PC_{1t})$$

Expressed statistically the model is:

$$Y_{1t} = \beta_{11} + I_{1t}\beta_{12} + P_{1t}\beta_{13} + PC_{1t}\beta_{14} + \varepsilon_{1t}$$

Where:
Y_{1t} = Harvest in county 1, year t
I_{1t} = Non-industrial growing stock inventory, in county 1, year t
P_{1t} = Stumpage price in county 1, year t
PC_{1t} = Per capita income in county 1, year t
ε_{1t} = Disturbance term for county 1, year t
β_{1I} = parameters to be estimated for county 1, year t

For an individual county in the study region, the model may be re-written in matrix form as:

$$\mathbf{y}_1 = \mathbf{x}_{11}\,\beta_{11} + \mathbf{x}_{12}\beta_{12} + \mathbf{x}_{13}\beta_{13} + \mathbf{x}_{14}\beta_{14} + \varepsilon_1$$

or: $y_1 = X_1\beta_1 + \ell_1$

Where, for the industrial landowner model:

$$y1=\begin{bmatrix} \mathbf{y}_{1,1} \\ \mathbf{y}_{1,2} \\ \vdots \\ \mathbf{y}_{1,25} \end{bmatrix} \quad X1=\begin{bmatrix} 1 & I_{1,1} & P_{1,1} & D_{1,1} \\ 1 & I_{1,1} & P_{1,1} & D_{1,1} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & I_{1,25} & P_{1,25} & D_{1,25} \end{bmatrix} \quad \beta=\begin{bmatrix} \beta_{1,1} \\ \beta_{1,2} \\ \vdots \\ \beta_{1,25} \end{bmatrix} \quad \ell=\begin{bmatrix} \ell_{1,1} \\ \ell_{1,2} \\ \vdots \\ \ell_{1,25} \end{bmatrix}$$

And for the non-industrial landowner model:

$$y1=\begin{bmatrix} \mathbf{y}_{1,1} \\ \mathbf{y}_{1,2} \\ \vdots \\ \mathbf{y}_{1,25} \end{bmatrix} \quad X1=\begin{bmatrix} 1 & I_{1,1} & P_{1,1} & PC_{1,1} \\ 1 & I_{1,1} & P_{1,1} & PC_{1,1} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & I_{1,25} & P_{1,25} & PC_{1,25} \end{bmatrix} \quad \beta=\begin{bmatrix} \beta_{1,1} \\ \beta_{1,2} \\ \vdots \\ \beta_{1,25} \end{bmatrix} \quad \ell=\begin{bmatrix} \ell_{1,1} \\ \ell_{1,2} \\ \vdots \\ \ell_{1,25} \end{bmatrix}$$

Thus, for the eight counties of the north coast region, a set of eight individual economic relations can be developed for both industrial and non-industrial landowners as:

$$\mathbf{y}_1 = \mathbf{x}_{11}\beta_{11} + \mathbf{x}_{12}\beta_{12} + \mathbf{x}_{13}\beta_{13} + \mathbf{x}_{14}\beta_{14} + \varepsilon_1$$

$$\mathbf{y}_2 = \mathbf{x}_{21}\beta_{21} + \mathbf{x}_{22}\beta_{22} + \mathbf{x}_{23}\beta_{23} + \mathbf{x}_{24}\beta_{24} + \varepsilon_2$$

$$\mathbf{y}_3 = \mathbf{x}_{31}\beta_{31} + \mathbf{x}_{32}\beta_{32} + \mathbf{x}_{33}\beta_{33} + \mathbf{x}_{34}\beta_{34} + \varepsilon_3$$

$$\mathbf{y}_4 = \mathbf{x}_{41}\beta_{41} + \mathbf{x}_{42}\beta_{42} + \mathbf{x}_{43}\beta_{43} + \mathbf{x}_{44}\beta_{44} + \varepsilon_4$$

$$\mathbf{y}_5 = \mathbf{x}_{51}\beta_{51} + \mathbf{x}_{52}\beta_{52} + \mathbf{x}_{53}\beta_{53} + \mathbf{x}_{54}\beta_{54} + \varepsilon_5$$

$$\mathbf{y}_6 = \mathbf{x}_{61}\beta_{61} + \mathbf{x}_{62}\beta_{62} + \mathbf{x}_{63}\beta_{63} + \mathbf{x}_{64}\beta_{64} + \varepsilon_6$$

$$\mathbf{y}_7 = \mathbf{x}_{71}\beta_{71} + \mathbf{x}_{72}\beta_{72} + \mathbf{x}_{73}\beta_{73} + \mathbf{x}_{74}\beta_{74} + \varepsilon_7$$

$$\mathbf{y}_8 = \mathbf{x}_{81}\beta_{81} + \mathbf{x}_{82}\beta_{82} + \mathbf{x}_{83}\beta_{83} + \mathbf{x}_{84}\beta_{84} + \varepsilon_8$$

Pooling the equations for each county yields a reformulated version as a single linear statistical model as:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \end{bmatrix} = \begin{bmatrix} X_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & X_2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & X_3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & X_4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & X_5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & X_6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & X_7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & X_8 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_7 \\ \beta_8 \end{bmatrix} + \begin{bmatrix} \ell_1 \\ \ell_2 \\ \ell_3 \\ \ell_4 \\ \ell_5 \\ \ell_6 \\ \ell_7 \\ \ell_8 \end{bmatrix}$$

or: $$y = X\beta + \ell$$

Where y represents a matrix of dimension (208x1), X represents a matrix of dimension (208x32), β represents a matrix of dimension (208x1), and e represents a matrix of (208x1) dimension. Essentially, y represents a vector of harvest volumes for each county in the study region (y_1, y_2, ... y_8) with 26 observations in each county for a total of 208 elements. The parameter X represents a matrix of 8 matrices (1 for each county) each containing the three independent variables and a row of 1's for the intercept term with 26 observations. Thus the X parameter is a 6656 element matrix containing all observations for the three independent variables. The β parameter and the e parameter represent column matrices of 8 vectors each with each vector containing 26 elements for a total of 208 elements in the β and e matrices.

The above model assumes that there is no contemporaneous correlation between disturbance terms for each county. That is, the error vectors are specified as:

$$\begin{bmatrix} \ell_1 \\ \ell_2 \\ \vdots \\ \ell_8 \end{bmatrix} \iota N \left[\begin{pmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{pmatrix}, \begin{pmatrix} \delta_1^2 I_t & \cdots & \cdots & 0 \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ 0 & \cdots & \cdots & \delta_8^2 I_t \end{pmatrix} = W \right]$$

This specification assumes that the off-diagonal elements of the covariance matrix are zero, or not contemporaneously correlated. Thus the generalized least squares estimator for the β vector is:

$$\hat{\beta} = \left(X'W^{-1}X\right)^{-1} X'W^{-1}y$$

However, because timber suppliers in the 8 county study region function in a common demand region, have similar forest types, and in general are subject to similar market forces, it is highly likely that the disturbance terms for each county are in fact contemporaneously correlated. Thus a new error vector needs to be specified in which the off-diagonal elements of the covariance matrix are non-zero contemporaneous covariances:

$$\begin{bmatrix} \ell_1 \\ \ell_2 \\ \vdots \\ \ell_8 \end{bmatrix} \iota \left[\begin{pmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{pmatrix}, \begin{pmatrix} \delta_{11}^2 I_t & \delta_{12}^2 I_t & \cdots & \delta_{18}^2 I_t \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \delta_{81}^2 & \cdots & \cdots & \delta_{88}^2 I_t \end{pmatrix} = W \right]$$

Where $\delta_{11} = \delta_{12} = ...=\delta_{88}$ are error covariances that reflect contemporaneous correlation. This approach allows the use of the seemingly unrelated regressions (SUR) technique for model estimation. This technique utilizes the generalized least squares (GLS) estimator:

$$\hat{\beta} = \left(X'W^{-1}X\right)^{-1} X'W^{-1}y$$

With a corresponding covariance matrix of:

$$\mathrm{cov}\left(\hat{\beta}\right) = \left(X' W^{-1} X\right)^{-1}$$

Where W^{1} is the inverse matrix of the covariance matrix that recognizes contemporaneous correlation between the error terms for each county in the study region.

However, because the W matrix is not known, an estimate is developed that makes use of the residuals from the individual ordinary least squares (OLS) regressions for each county. An estimate of W is thus:

$$\hat{W} = \begin{bmatrix} \hat{\delta}_{11}\, I_t & \cdots & \cdots & \cdots & \hat{\delta}_{18} I_t \\ \hat{\delta}_{21} I_t & \ddots & & & \vdots \\ \vdots & & \ddots & & \vdots \\ \vdots & & & \ddots & \vdots \\ \hat{\delta}_{81} I_t & \cdots & \cdots & \cdots & \hat{\delta}_{88} I_t \end{bmatrix}$$

Advantages of SUR Models

Utilizing the estimated covariance matrix $\hat{W}$ allows parameter estimates to be made which incorporate the contemporaneous correlation between harvests in the eight counties of the study region. If the contemporaneous correlation between counties is found to be statistically significant, parameter estimates which incorporate the $\hat{W}$ matrix must, by definition, be more efficient than those developed by OLS. The SUR approach has found some application in econometric analysis. Alig (1986) used a SUR approach in an analysis of factors affecting forestland acreage trends in the southern United States. Additionally, a study by Frecka and Lee (1988) found that SUR performed better than OLS in terms of parameter estimation and forecasting of financial ratios for firms in the food and kindred products industry.

Determining when this approach to modeling is appropriate is essentially a matter of determining when ordinary least squares estimates are equal to SUR estimates. This can occur under two circumstances (Griffiths, Hill, and Judge, 1993). The first situation is when there is no contemporaneous correlation between equations, that is, when $\delta_{12} = \delta_{13} = \ldots = \delta_{ij} = 0$ and thus the covariance matrix W has off-diagonal elements that are all zero. Secondly, OLS estimates are equal to SUR estimates when data for the explanatory variables in each of the equations are identical. In practice, estimates computed using SUR are likely to be more efficient than OLS estimates when the dissaggregated units represented by the individual equations are subject to similar demand forces, have similar land ownership patterns, or have similar forest types.

Data Sources

For each county in the study region, annual time series data were collected for the period 1968 to 1993 (26 years). For many of the key variables, complete data sets were available. For other variables however, complete time series are not available and values for missing years need to be calculated. In addition, county-specific time series data are not available for stumpage prices or discount rates and thus the same data series for these variables were applied to all of the counties. This section details the sources and/or methods of projection for variables used in the present study. Complete data sets used in the analysis are included as Appendix A.

Harvest Volume

For years 1968 to 1976 annual harvest volumes for the eight counties in the study region were taken from annual reports compiled by the Pacific Northwest Forest and Range Experiment Station, US Forest Service (USFS). Specific values in the reports were supplied by the Oregon State Forester. For Years 1977 to 1993, harvest volumes for the individual counties were those reported in the Oregon Department of Forestry (ODF) Annual Harvest Reports. These volumes are those reported to the Oregon Department of Revenue (ODR) for taxation purposes by the individual landowners following harvest.

Regardless of source, all harvest volumes used in the present study were reported in thousands of board feet (MBF), Scribner Log Rule. The use of harvest volumes reported in Scribner board feet may introduce some bias when using time series data due to the fact that The Scribner Log Rule was developed for use with large diameter "old growth" logs. This bias toward large diameter logs means that actual harvest volume in a region such as the North Coast, where much of the harvest consists of smaller diameter "second growth", may underestimate the true cubic volume harvested. Correcting for this problem however would resulting in additional assumptions being made with regard to historical cubic foot/board foot ratios in the study region. Additionally, historical harvesting patterns in the study region indicate that much of the large diameter timber was harvested in the region prior to 1968: the first year of recorded data used in this study.

Stumpage Price

As a proxy for private stumpage prices, average prices for Douglas-fir export logs were used in both the industrial and non-industrial models. Prices used in the analysis are those reported in quarterly and annual reports by the US Forest Service (Holt, 1974) (Warren, 1994). Prices were adjusted to constant US dollars (1982 = 100) using the Lumber, Douglas-fir, Other Lumber Softwoods, producers price index which is reported on a monthly basis by the US Department of Commerce. This deflator is intended to represent an industry-specific price deflator reflective of inflationary influences in the forest products industry. For the purposes of this study, annual values were calculated by averaging the monthly values for a given year.

The use of export prices as a proxy for private stumpage prices has several advantages. First, export prices in the study region have traditionally been higher than for other markets thus the export price is that which may have the most influence on private harvesting decisions. Secondly, due to restrictions on the export of public timber, the use of export prices eliminates confounding role that public timber plays in other markets. Export prices therefore, though reflective of the log market rather than the stumpage market, nevertheless indicate prices for private stumpage given the assumption that stumpage prices are derived from the log market.

Growing Stock Inventory

Annual data for levels of growing stock for counties in the study region are unavailable. Therefore projections must be made for years in which data are lacking. Using published data from forest inventories conducted in western Oregon in 1963 (Metcalf and Hazard, 1964), 1975-77 (Gedney, 1982), and 1984-86 (Gedney, Bassett, and Mei, 1987), fitted linear trend models were developed for both industrial and non-industrial landowners in each of the study counties (Table 4.). These models were then used to calculate levels of growing stock in each county for years in which adequate data are unavailable.

With the exception of Washington County, the fitted linear models are based on three data points; one for each year in which an inventory was conducted in that county. For Washington County, inventory data were not published for industrial landowners for the 1963 inventory therefore the fitted linear model for industrial growing stock in that county is based on two data points, one from the 1976 inventory and one from the 1986 inventory.

Table 4. Growing Stock Trend Models

County	Industrial Trend Model	Non-industrial Trend Model
Benton	24.4712 + 11.015*T	523.184 - 14.5526*T
Clatsop	1123.97 - 17.7978*T	337.186 - 9.63896*T
Columbia	424.806 +17.0645*T	321.159 - 1.41191*T
Lincoln	1125.11 - 18.4699*T	207.679 + 1.81955*T
Polk	189.375 + 14.7469*T	194.563 - 1.86725*T
Tillamook	457.811 - 5.38586*T	340.337 - 10.6253*T
Washington	99.6667 + 7.8889*T	236.285 + 1.8536*T
Yamhill	184.861 + 4.11042*T	219.084 + 0.843672*T

Two potential problems exist with this approach to projecting growing stock inventories. First, because the linear trend models are based on a "best fit" line of the data points, the presence of significant variability between data points may lead to models with a high degree of inherent variability. Projections made with such models thus have to be considered with this inherent variability in mind. Counties which exhibit little variability between inventories will have relatively precise projections, while counties which exhibit a large amount of variability between inventories will have relatively imprecise projections. This problem is exacerbated by the limited number of data points upon which the trend models are based. Table 5 shows the data used to develop trend lines for each county and landowner, and the coefficient of variation for those data.

Table 5. Inventory Data: Oregon Coast Counties

	Industrial Inventory (million cubic feet)				Non-industrial Inventory (million cubic feet)			
County	**1963**	**1976**	**1986**	**CV**	**1963**	**1976**	**1986**	**CV**
Benton	61	120	322	67%	511	314	177	41%
Clatsop	1186	653	821	25%	345	148	133	46%
Columbia	423	729	805	25%	317	307	283	5%
Lincoln	1086	914	655	20%	190	278	226	16%
Polk	184	462	512	37%	198	153	158	12%
Tillamook	427	442	289	18%	334	170	92	51%
Washington	-	218	289	14%	246	244	293	9%
Yamhill	188	249	282	16%	230	206	255	9%

A second potential problem with the use of county level inventory data arises from the standard errors associated with the growing stock estimates in each county. The estimates of growing stock in each of the sample years is based on a grid of field sample plots. The estimates of growing stock inventories for the counties are therefore based on differing numbers of samples, with large counties having more samples upon which their estimates are based, than small counties. This difference in the number of samples among counties can lead to lead to different standard errors associated with each county's estimate of growing stock inventory. Given a constant coefficient of variation among the forest stands sampled in each of the counties, it would be expected that the estimates of growing stock inventory in larger counties would be more precise than estimates for smaller counties due to the larger sample sizes in larger counties.

An additional potentially confounding factor associated with the use of published forest inventory data is that the reported data do not reflect changes in land use between samples. In other words, a negative trend indicating a declining level of growing stock may be due to land use shifts from forest to non-forest uses rather than trends in timber harvesting. This may be particularly acute on non-industrial lands in counties near urban growth areas where urban development pressures have increased in the recent past. In a study of land use changes and timber harvesting practices, Lettman (1995) indicates that industrial private timberland in western Oregon is not being converted to non-forestry uses. However, during the period 1982 - 1994, approximately three percent of non-industrial forest lands in western Oregon shifted from less developed to more developed status. Thus, trends in growing stock inventories on non-industrial private lands may be influenced by shifts in land use rather than by per acre trends as influenced by timber harvesting.

Discount Rate

For the discount rate used in the industrial landowner model, the prime rate on commercial paper, as reported by dealers as their daily averages, was used as a proxy variable. This choice is intended to be a reflection industrial landowners' alternative borrowing rate. The rates used in this study were those reported by the Board of Governors of the Federal Reserve System.

Per Capita Income

Annual per capita income data for each of the counties were derived from US Department of Commerce statistics (USDOC, 1994). Income was reported for each year in US dollars ($). Data for each county were adjusted for inflation using the purchasing power of the dollar as determined by the Consumer Price Index (CPI) (1982-84 = $1.00) by the Bureau of Labor Statistics. A potential problem with using the CPI as a deflator is the possibility that the "market basket" of goods used to calculate the index is not reflective of the "market basket" of the landowners in the study region. However, the CPI does give a general indication of the real value of income levels over time, and in addition, is readily available from many economic reporting services.

Model Estimation and Testing

Following data compilation, a statistical computer software package was used to estimate parameters and test hypotheses. Prior to estimation using an error-related model data were tested for autocorrelation and heteroskedasticity using ordinary least squares (OLS) estimates. Following estimation with a set of error-related equations, errors were tested for contemporaneous correlation, and a restricted model was tested to determine if harvests for counties in the study region could be modeled with a common coefficient vector.

Test for Autocorrelation

Prior to estimation using the seemingly unrelated regressions (SUR) technique, models for each of the counties and landowners in the study region were estimated using ordinary least squares (OLS) to test for the presence of autocorrelated (AR(1)) errors.

The hypothesis test for autocorrelated errors is expressed as:

Ho: $\rho = 0$ (no autocorrelation)

Ha: $\rho > 0$ (autocorrelation exists)

Using the Durbin-Watson statistic, the hypothesis is tested using the Durbin-Watson bounds test:

1) If $DW < D_L$, reject Ho
2) If $DW > D_u$, do not reject Ho
3) If $D_L < DW < D_u$, test is inconclusive

Where D_L and D_U represent the lower and upper bounds, respectively, of the Durbin-Watson statistic at the 95% confidence level.

Test for Heteroskedasticity

Individual OLS models for each county and landowner were also tested for the presence of heteroskedastic errors prior to estimation with SUR. White's Test was used to test for heteroskedasticity using the test statistic:

$$NR^2 \approx \chi^2$$

Where N is the number of observations (26) and R^2 is the sum of squared residuals from an "auxiliary regression" in which the squared residuals from the OLS estimation are regressed against the original variables in the OLS model, plus all cross products of the original variables. Essentially, White's test is a test of the explanatory power of the residuals from the OLS estimates, thus models with residuals that have high explanatory power would be suspect of having heteroskedastic errors and models that have residuals with low explanatory power would not be suspected of having heteroskedastic errors.

SUR Model Estimation

The combined eight county model for both industrial and non-industrial landowners was estimated using the seemingly unrelated regressions statistical model (SUR) which incorporates the contemporaneously correlated error structure. Estimation was complete with SAS/ETS software (SAS Institute, 1993) using the PROC SYSLIN SUR procedure. Complete SAS programs used in the analysis are included in Appendix B.

Test for Contemporaneous Correlation

To test the statistical significance of the contemporaneous correlations calculated with SUR, the hypothesis was tested that error terms across equations were equal:

Ho: $\delta_{12} = \delta_{13} = \delta_{78}$ (no contemporaneous correlation)

Ha: at least one δ_{ij} is not equal (contemporaneous correlation)

To test the hypothesis the test statistic:

$$\lambda = T(r^2_{12} + r^2_{13} + \ldots + r^2_{78}) \approx \chi^2$$

was used. Where T is the number of observations and $(r^2_{12} + r^2_{13} + \ldots + r^2_{78})$ is the sum of squared contemporaneous correlations between the error terms for each of the study counties. The statistic λ is a random variable that, in large sample is distributed according to a Chi-squared distribution with $j(j-1)/2$ degrees of freedom.

Restricted Model Estimation and Testing

In order to test the possibility that the coefficient vectors across counties are equal, an additional SUR model was estimated in which the restriction:

$$\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8$$

was imposed. That is, for the industrial models, the coefficients on price, growing stock inventory, and discount rate were each set equal across counties. Likewise, for the non-industrial models, the coefficients on price, growing stock inventory and per capita income were each set equal across counties.

To test the statistical validity of using the restricted models rather than the unrestricted models, the following hypothesis was tested using a generalized error covariance version of an F-test:

Ho: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8$

Ha: at least one β_I is not equal

Empirical Results

This section presents empirical results of the present study. Included are ordinary least squares estimation results, the results of tests for autocorrelated and heteroskedastic errors, and results of the SUR model estimation. Associated testing procedures for contemporaneously correlated errors are also presented. In addition, results of the restricted model estimation and testing are given.

Ordinary Least Squares: Industrial Landowner Model

Results of OLS estimation for the industrial landowner model are presented in Table 6 for each county in the study region. Estimation with OLS results in mixed results with respect to *a priori* expectations for individual variables in the present net worth maximization model. Price was significant at the .05 significance level in three of the counties, and in four of the counties had the expected positive sign. However, for other counties price had either an unexpected negative sign and/or a high standard error. Of the four counties with the unexpected negative sign, three had coefficients that were not significantly different than zero at the .10 significance level.

Coefficients estimated for the growing stock inventory variable presented less mixed results. For all of the counties except Lincoln County, the estimated coefficients on the growing stock inventory variable had both the expected positive signs and were significant at the .05 significance level. For Lincoln County, the coefficient with an unexpected negative sign was not significantly different than zero, indicating either model miss-specification for that county, or a faulty trend projection for the county's level of industrial growing stock

Table 6. Ordinary Least Squares Results: Industrial Landowner Model

County	Constant	Price	Discount Rate	Inventory	R^2
Benton	6130.87	72.56	-1158.96	111.68	.5040
(std. error)	(13751)	(52.54)	(1017.05)	(46.42)	
(p-value)	(.6601)	(.1811)	(.2667)	(.0250)	
Clatsop	-24850	6.58	-10136	333.11	.5761
	(118395)	(168.82)	(3267.17)	(92.18)	
	(.8357)	(.9693)	(.0052)	(.0015)	
Columbia	-104731	-358.24	2732.54	458.37	.8190
	(26391)	(79.61)	(1539.19)	(45.32)	
	(.0007)	(.0002)	(.0897)	(.0001)	
Lincoln	150797	249.26	-11585	-3.99	.5327
	(83833)	(123.11)	(2382.16)	(64.76)	
	(.0858)	(.0552)	(.0001)	(.9514)	
Polk	-2505.70	-35.05	-499.42	200.50	.7685
	(12001)	(43.57)	(842.84)	(28.71)	
	(.8365)	(.4298)	(.5595)	(.0001)	
Tillamook	-323586	199.87	-1028.41	989.45	.6468
	(80232)	(88.95)	(1721.47)	(160.57)	
	(.0006)	(.0350)	(.5563)	(.0001)	
Washington	-24257	-4.53	-1165.01	252.84	.8089
	(7826.33)	(28.51)	(550.94)	(35.13)	
	(.0052)	(.8753)	(.0460)	(.0001)	
Yamhill	-108264	-30.06	-660.92	614.27	.8119
	(15647)	(32.78)	(633.52)	(77.52)	
	(.0001)	(.3692)	(.3082)	(.0001)	

The coefficients estimated on the discount rate variable also presented mixed results with regard to expectations proposed by the theoretical model. For three of the counties the coefficients were significant at the .05 significance level and one was significant at the .10

level. However, with the exception of Columbia County, all coefficients for the discount rate were negative; contrary to the expectations postulated by the theoretical model.

Test for Autocorrelation

Results of the test for autocorrelated (AR(1)) errors in the industry landowner data are presented in Table 7. In all cases, except for Benton, Clatsop, and Lincoln counties, we fail to reject, or find inconclusive, the null hypothesis of no autocorrelation.

Table 7. Autocorrelation Testing Results: Industry Model

County	DW	D_L	D_U	Result
Benton	1.082	1.143	1.652	Reject
Clatsop	1.104	1.143	1.652	Reject
Columbia	1.763	1.143	1.652	Fail to reject
Lincoln	1.033	1.143	1.652	Reject
Polk	1.338	1.143	1.652	Inconclusive
Tillamook	1.691	1.143	1.652	Fail to reject
Washington	1.304	1.143	1.652	Inconclusive
Yamhill	2.488	1.143	1.652	Fail to reject

Thus for five of the counties in the study region we can safely assume that an AR(1) process is not occurring in the error structure. For the other three counties, the Durbin-Watson statistics indicate that the test for autocorrelated error is nearly inconclusive. Therefore, for the remainder of the analysis for this study, the AR(1) process in those counties was ignored. These results also ignore the possibility that autoregressive processes other than AR(1) may be occurring in the data. To analyze for other AR processes however would require additional time series analysis which is beyond the scope of the present study.

Test for Heteroskedastic Errors

Results of White's Test for heteroskedastic errors in the industry landowner analysis are presented in Table 8. The Chi-squared critical value with 6 degrees of freedom and a 5% significance level is 12.5916. Therefore, for each county in the study region there is insufficient evidence to suggest that a heteroskedastic error structure exists; the null hypothesis of homoskedastic errors is not rejected.

Table 8. Test for Heteroskedastic Errors: Industry Model

County	R^2	N	W	Result
Benton	.1923	26	4.9998	Fail to reject
Clatsop	.2523	26	6.5598	Fail to reject
Columbia	.2396	26	6.2296	Fail to reject
Lincoln	.2580	26	6.7080	Fail to reject
Polk	.2772	26	7.2072	Fail to reject
Tillamook	.2532	26	6.5832	Fail to reject
Washington	.0869	26	2.2594	Fail to reject
Yamhill	.4820	26	12.5320	Fail to reject

Ordinary Least Squares: Non-industrial Model

Ordinary least squares estimation results for the non-industrial landowner model are presented in Table 9 for each of the counties in the study region. Model fitting results are characterized by moderate to low explanatory power and coefficients with high standard errors. The signs on individual coefficients, while contrary to *a priori* expectations, are consistent with the findings of other studies in western Oregon.

Table 9. Ordinary Least Squares Results: Non-industrial Landowner Model

County	Constant	Price	Income	Inventory	R^2
Benton	30939	-37.08	0.112	-14.54	.0599
(std. error)	(65854)	(29.31)	(4.41)	(64.11)	
(p-value)	(.6431)	(.2192)	(.9800)	(.8227)	
Clatsop	13076	-12.31	0.832	-46.58	.3494
	(23267)	(18.59)	(1.62)	(28.93)	
	(.5798)	(.5148)	(.6128)	(.1216)	
Columbia	274225	-62.13	2.62	-865.31	.4303
	(138620)	(40.35)	(4.02)	(352.89)	
	(.0606)	(.1379)	(.5221)	(.0226)	
Lincoln	23890	-38.90	-14.10	669.49	.2382
	(90013)	(78.94)	(5.88)	(561.87)	
	(.7932)	(.6271)	(.0253)	(.2461)	
Polk	62211	-22.49	-0.554	-237.67	.1452
	(43862)	(20.12)	(2.21)	(150.33)	
	(.1701)	(.2757)	(.8044)	(.1282)	
Tillamook	16775	-8.42	-0.157	-34.20	.3542
	(1302)	(11.30)	(.9691)	(12.32)	
	(.1519)	(.4642)	(.8731)	(.0110)	
Washington	-177578	-67.93	-1.28	880.54	.5936
	(35285)	(25.45)	(2.35)	(222.75)	
	(.0001)	(.0140)	(.5921)	(.0007)	
Yamhill	-201385	-27.80	0.546	922.71	.5139
	(55555)	(19.00)	(1.99)	(305.17)	
	(.0015)	(.1577)	(.7871)	(.0062)	

All of the coefficients estimated for price had an unexpected negative sign and only one was significant at the .05 significance level. For growing stock inventory, five of the estimated coefficients had an unexpected sign and four of the coefficients were significant at the .05 significance level. This would indicate that timber harvest in the study region by non-industrial landowners is inversely related to price and inventory; contrary to expectations upon which the theoretical model is based. These findings are, however, consistent with the findings of Adams and Haynes (1990) who found declining non-industrial harvests despite rising prices and inventories.

Four of the coefficients estimated for the income variable had the expected negative sign, however, only one coefficient was significantly different than zero at the .05 significance level. These findings suggest that for non-industrial landowners in the study region, per capita income does not appear to significantly influence timber harvest volume. This finding is consistent with those of Cleaves and Bennett (1995) who found similar rates of harvest participation among non-industrial landowners in western Oregon regardless of income.

Test for Autocorrelation

Results of tests for autocorrelated errors in the non-industrial models are presented in Table 10. For all of the counties except Clatsop, Lincoln, and Tillamook, the test results are inconclusive for an AR(1) process.

Table 10. Autocorrelation Testing Results: Non-industrial Model

County	DW	D_L	D_U	Result
Benton	1.225	1.143	1.652	Inconclusive
Clatsop	.757	1.143	1.652	Reject
Columbia	1.298	1.143	1.652	Inconclusive
Lincoln	1.018	1.143	1.652	Reject
Polk	1.415	1.143	1.652	Inconclusive
Tillamook	.845	1.143	1.652	Reject
Washington	1.299	1.143	1.652	Inconclusive
Yamhill	1.467	1.143	1.652	Inconclusive

Just as in the test for autocorrelation in the industrial model, this test does not rule out the possibility of an auto regressive process in the data other than an AR(1) process. Also, because the test for AR(1) are largely inconclusive, the autoregressive process is ignored for the remainder of this analysis for the non-industrial landowner model.

Test for Heteroskedastic Errors

Results of White's test for heteroskedastic errors in the non-industrial landowner analysis are presented in Table 11. Using the same degrees of freedom as in the industrial model, the Chi-squared critical value at a 5% significance level is again 12.5916. Therefore for each county in the study region, with the exception of Lincoln County, we find insufficient evidence to suggest that a heteroskedastic error structure exists.

Table 11. Test for Heteroskedastic Errors: Non-industrial Model

County	R^2	N	W	Result
Benton	.2840	26	7.3840	Fail to Reject
Clatsop	.1578	26	4.1028	Fail to Reject
Columbia	.1960	26	5.0960	Fail to Reject
Lincoln	.5268	26	13.6968	Reject
Polk	.0852	26	2.2152	Fail to Reject
Tillamook	.2907	26	7.5582	Fail to Reject
Washington	.0902	26	2.3452	Fail to Reject
Yamhill	.1501	26	3.9026	Fail to Reject

SUR Model Estimation: Industrial Landowner Model

Results of the industrial landowner model estimation which account for a contemporaneously correlated error structure are presented in Table 12. The system-weighted R^2 value for the estimated SUR model is .7076 indicating that a significant amount of the variation in harvest across all of the counties is explained by the SUR model.

Table 12. SUR Model Estimation Results: Industrial Landowner Model

County	Constant	Price	Discount Rate	Inventory
Benton	6132.69	72.48	-1158.40	111.79
(std. error)	(13751)	(52.54)	(1017.05)	(46.42)
(p-value)	(.6600)	(.1817)	(.2670)	(.0249)
Clatsop	-25780	7.60	-10143	333.89
	(118394)	(168.82)	(3267.17)	(92.18)
	(.8296)	(.9645)	(.0052)	(.0015)
Columbia	-104957	-359.03	2737.60	458.996
	(26391)	(79.61)	(1539.19)	(45.32)
	(.0006)	(.0002)	(.0891)	(.0001)
Lincoln	149963	250.21	-11591	-3.30
	(83832)	(123.11)	(2382.16)	(64.76)
	(.0874)	(.0544)	(.0001)	(.9599)
Polk	-2518.96	-35.15	-498.73	200.59
	(12001)	(43.57)	(842.84)	(28.70)
	(.8357)	(.4284)	(.5601)	(.0001)
Tillamook	-324491	200.62	-1033.19	991.34
	(80229)	(88.95)	(1721.46)	(160.56)
	(.0005)	(.0344)	(.5545)	(.0001)
Washington	-24262	-4.57	-1164.75	252.91
	(7826.32)	(28.51)	(550.94)	(35.13)
	(.0052)	(.8741)	(.0461)	(.0001)
Yamhill	-108228	-29.995	-661.32	614.06
	(15647)	(32.78)	(633.52)	(77.52)
	(.0001)	(.3701)	(.3079)	(.0001)

The estimation results by SUR represent a modest improvement over the OLS results for explaining industrial landowner harvests. For all of the counties, standard errors either remain the same or are reduced. Standard errors are reduced on the constant coefficient for Lincoln, Tillamook and Washington counties, and on the discount rate coefficient in the Tillamook county model. Additionally, the standard errors on the inventory coefficient are smaller for Polk and Tillamook counties.

SUR Model Estimation: Non-industrial Landowner Model

Results of the SUR model estimation that incorporate a contemporaneously correlated error structure for non-industrial landowner harvests are presented in Table 13. The system weighted R^2 value calculated for the models is .5417.

Table 13. SUR Model Estimation Results: Non-industrial Landowner Model

County	Constant	Price	Income	Inventory
Benton	53264	-35.84	-1.54	-34.55
(std. error)	(41435)	(29.01)	(2.68)	(41.81)
(p-value)	(.2120)	(.2297)	(.5710)	(.4174)
Clatsop	15764	-10.81	0.576	-48.25
	(17963)	(18.51)	(1.18)	(24.63)
	(.3897)	(.5653)	(.6305)	(.0629)
Columbia	306169	-53.22	1.098	-928.33
	(112453)	(38.52)	(2.74)	(303.20)
	(.0124)	(.1810)	(.6922)	(.0057)
Lincoln	26015	-38.78	-13.80	646.70
	(88930)	(78.85)	(5.16)	(532.37)
	(.7726)	(.6277)	(.0139)	(.2373)
Polk	57014	-20.96	-0.426	-216.81
	(28005)	(19.33)	(1.06)	(113.35)
	(.0540)	(.2900)	(.6929)	(.0689)
Tillamook	5204	-9.13	0.895	-25.49
	(8454)	(11.22)	(.657)	(11.19)
	(.5445)	(.4246)	(.1869)	(.0328)
Washington	-165981	-68.71	-0.058	776.97
	(32349)	(25.17)	(1.49)	(173.86)
	(.0001)	(.0122)	(.9694)	(.0002)
Yamhill	-198699	-26.05	0.406	915.09
	(50833)	(18.59)	(1.47)	(264.80)
	(.0008)	(.1751)	(.7852)	(.0023)

The SUR estimates for non-industrial landowners represent a considerable improvement over estimates obtained using ordinary least squares. For all of the counties except Tillamook and Washington, standard errors for the constant coefficient were smaller, and for the coefficient on income, all of the standard errors were smaller with the exception of Clatsop, Columbia, and Washington counties. There were also improvements in standard errors in all counties except Tillamook for the coefficient on inventory. Coefficients on price had smaller standard errors in the models for Tillamook and Washington counties.

Test for Contemporaneous Correlation

To test the significance of the contemporaneous correlations calculated with the SUR model, the sum of the squared cross model correlations was multiplied by the number of observations, to obtain, for the industrial landowner model, the test statistic:

$$\lambda = (26)(1.685262) = 43.8168$$

And for the non-industrial landowner model:

$$\lambda = (26)(7.507111) = 195.1849$$

The Chi-squared critical value (λ_c) for λ at the 5% significance level is 41.3371. Therefore for both the industrial landowner, and the non-industrial landowner models, $\lambda > \lambda c$ and the null hypothesis of no contemporaneous correlation is rejected in favor of the alternative hypothesis of significant contemporaneously correlated errors.

Due to the significance of the contemporaneously correlated error model, the estimates obtained by SUR for the individual counties must, by definition, be more efficient estimators than those obtained by ordinary least squares estimation. Therefore the models estimated for individual counties using SUR will provide more precise estimates of timber harvests for industrial and non-industrial landowners in the study region.

Restricted Model Estimation and Testing

Estimation of a restricted model, where coefficients on parameters were set equal across equations, resulted in the following model for industrial landowners:

$$\underset{}{HARVEST = INTERCEPT} \; \underset{\substack{(13.99)\\(.1203)}}{+22.62P} \; \underset{\substack{(309.99)\\(.1674)}}{-\,442.61D} \; \underset{\substack{(14.49)\\(.0001)}}{+\,180.06I}$$

And for non-industrial landowners:

$$\underset{}{HARVEST = INTERCEPT} \; \underset{\substack{(6.30)\\(.0055)}}{+\,19.38P} \; \underset{\substack{(0.41)\\(.0024)}}{+\,1.41PC} \; \underset{\substack{(3.34)\\(.0001)}}{+\,27.00I}$$

The system-weighted R^2 values for the two restricted models are .3889 for the industrial landowner model and .1648 for the non-industrial landowner model. In the industrial model signs on the coefficients satisfy *a priori* notions and one of the coefficients is significant at the .05 confidence level. In the non-industrial model all signs on coefficients satisfy *a priori* notions with the exception of the sign on the personal income coefficient. Intercept terms, which are the only terms which vary between counties in the restricted model, are presented in Table 14.

Table 14. Restricted Model Intercept Terms

County	Industrial Model	Non-industrial Model
Benton	2623	-13034
Clatsop	18356	-16649
Columbia	-7932	-5028
Lincoln	-6836	-10014
Polk	-13385	-14689
Tillamook	26273	-17688
Washington	-21817	-14225
Yamhill	-16331	-17194

To test the validity of the common coefficient vectors, F-tests were used to test the significance of the restrictions placed on the models. For the industrial model, the calculated F-statistics for the restrictions on the price, discount rate, and inventory coefficients were, respectively, 7.27, 6.07, and 11.89. For the non-industrial model, the calculated F-statistics on price, per capita income, and inventory were, respectively, 2.63, 2.08, and 5.09. In all cases the empirical F-statistic is greater than the F-statistic critical value ($F>F_C$), therefore the null hypothesis that the parameters have a common coefficient vector is rejected.

Historical Simulation

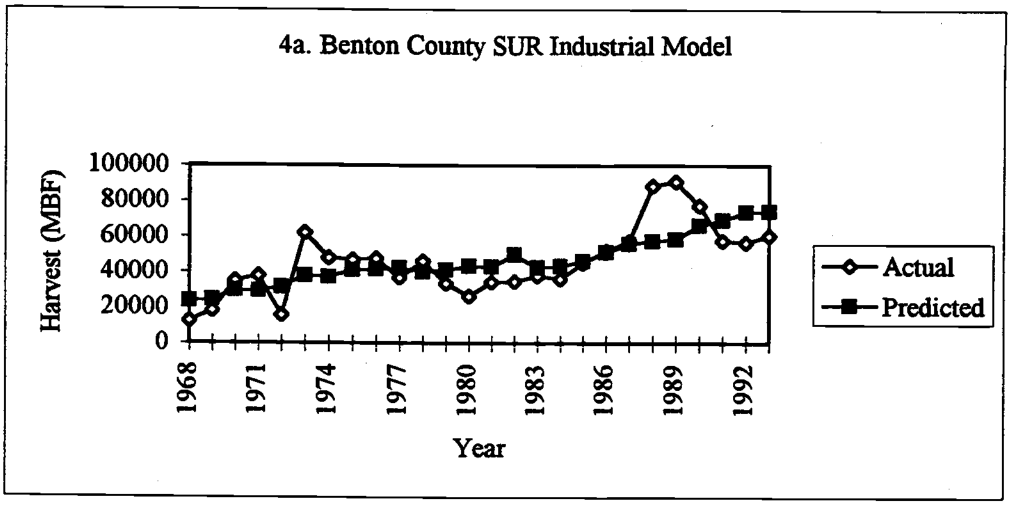
To evaluate the predictive capabilities of the models developed for each county using SUR, a simulation was run using actual data values for the period 1968 to 1993. Graphical representation of the simulation results are presented in Figures 5a-h for industrial landowners, and in Figures 6a-h for non-industrial landowners.

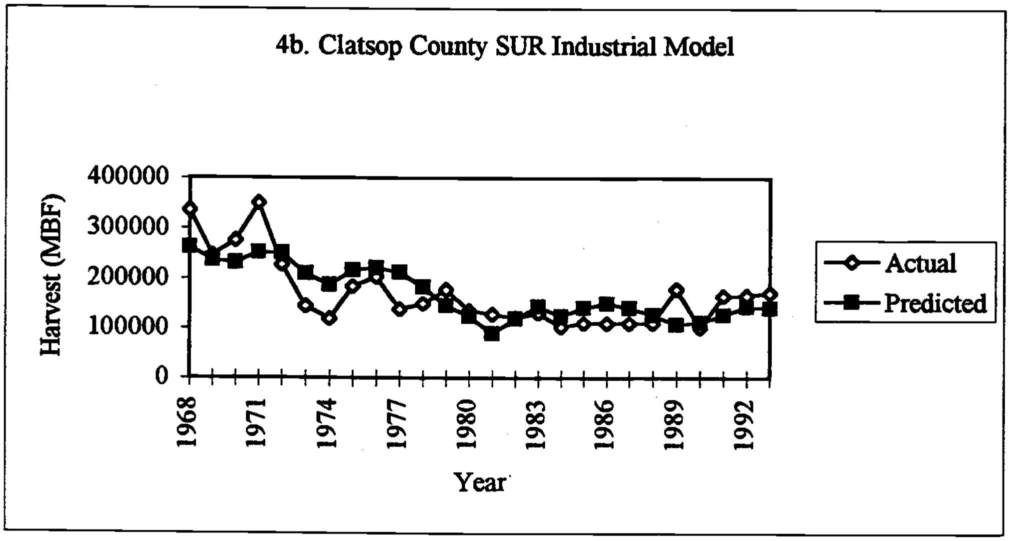
Additional Analysis: Non-industrial Model

Due to the poor fitting results and low explanatory power found for the non-industrial model, additional analyses were conducted in an attempt to improve the explanatory power of the model for those landowners. The large standard error associated with individual parameter coefficient estimates in the non-industrial model indicated that collinearity may be present between two or more of the independent variables. This may cause individual coefficient estimates to be fragile or non-robust.

An analysis of the correlations between independent variables was conducted to determine the extent of possible collinearity between independent variables. In each county, the results showed a significant amount of correlation between income and growing stock inventory indicating that these variables are collinear (Table 15.)

Figure 5a-h. Historical Simulation Plots: Industrial SUR Models





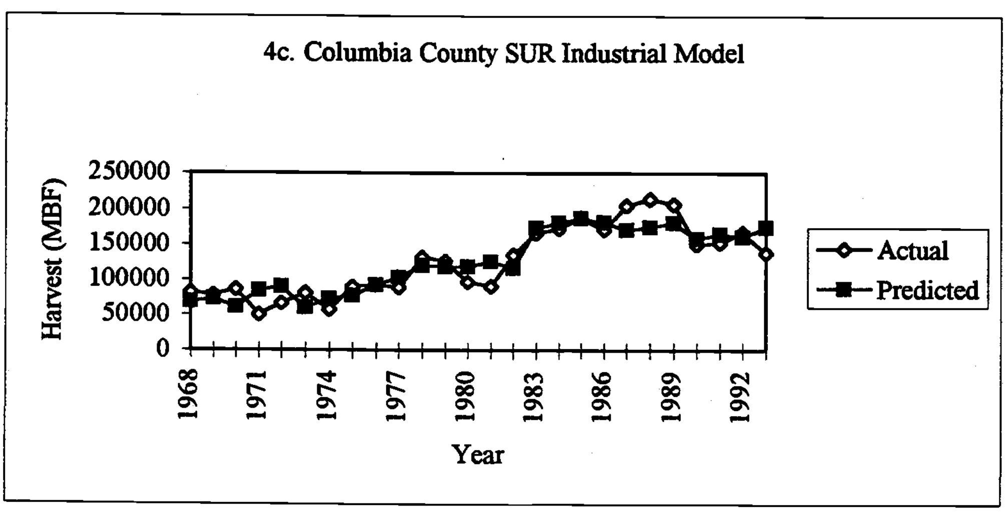
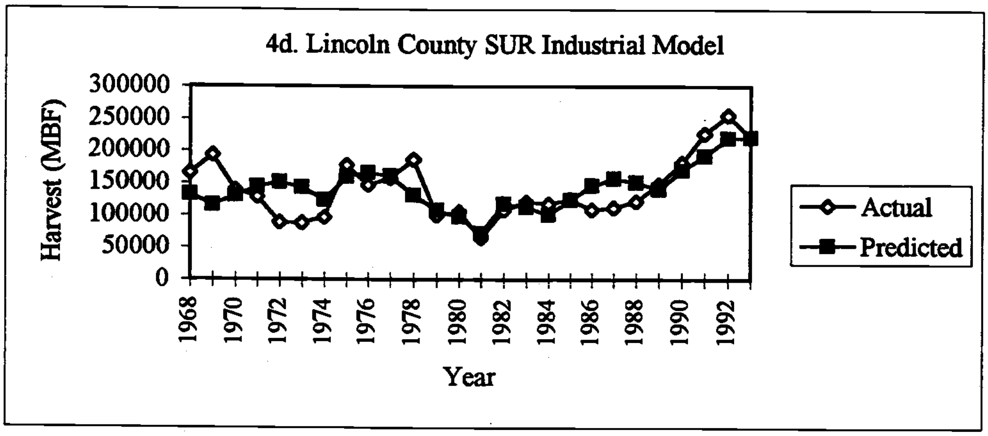
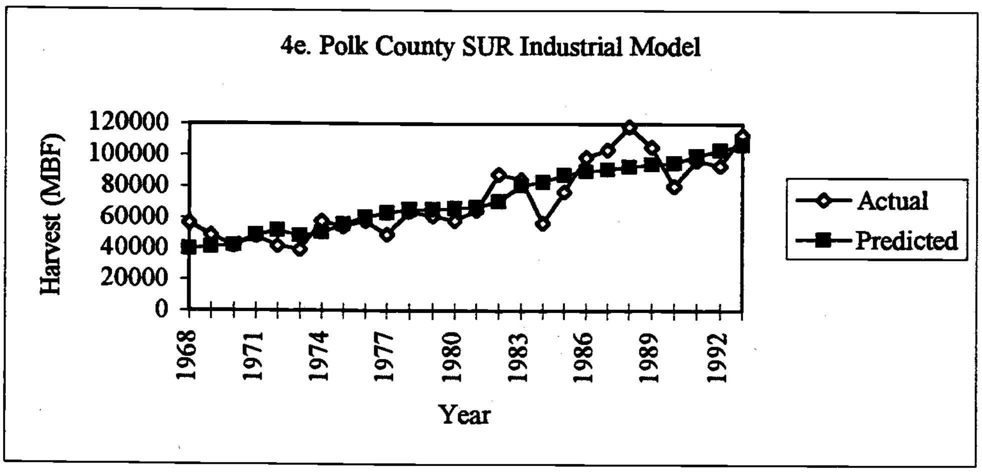


Figure 5. (Continued)





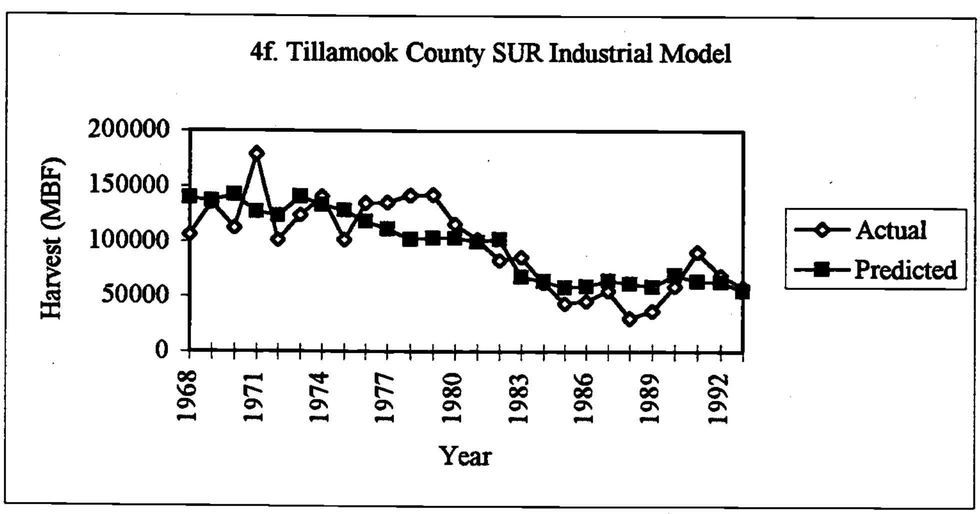
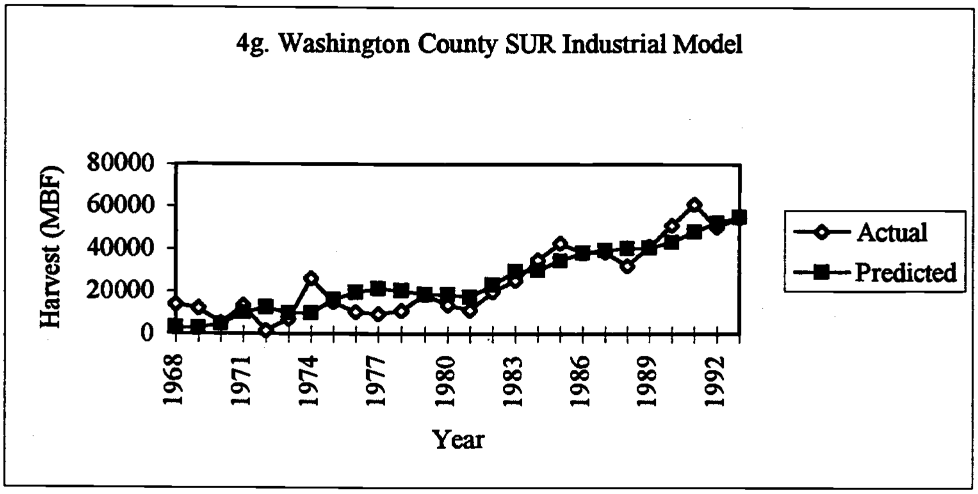


Figure 5. (Continued)



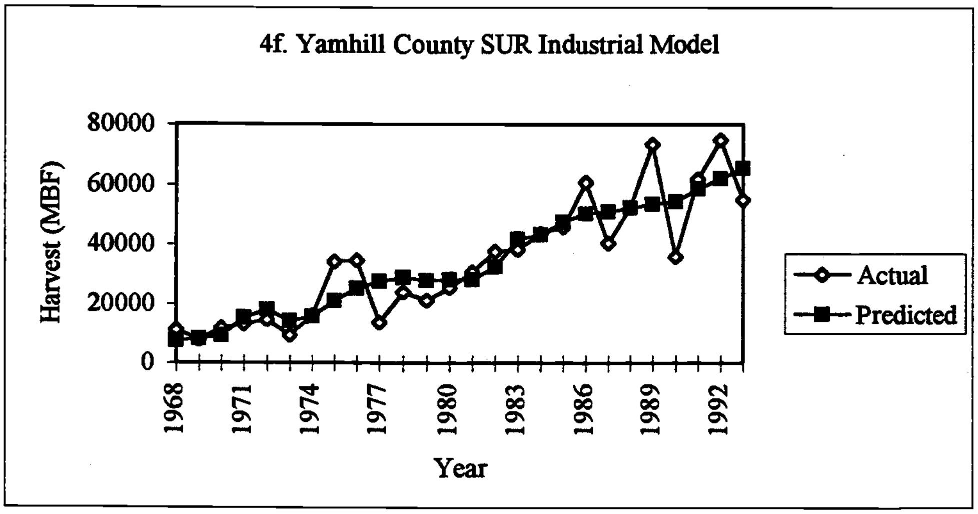
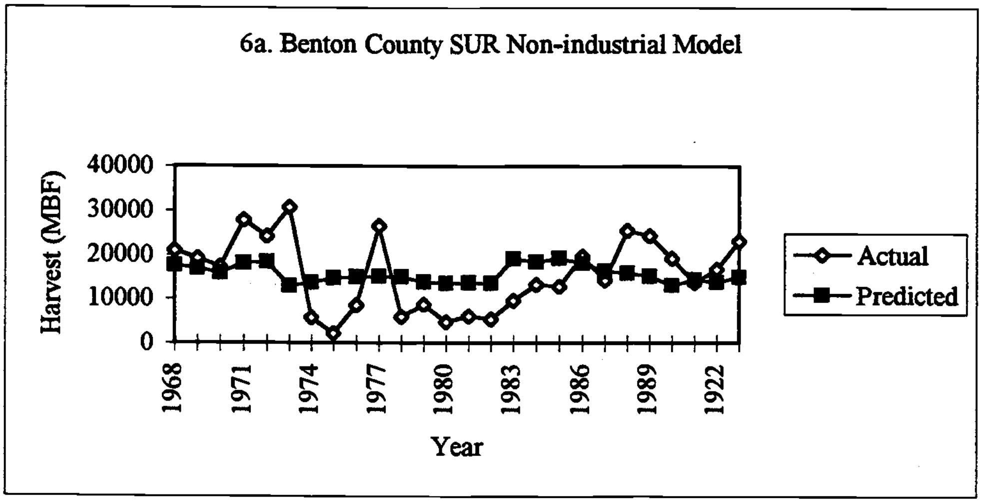
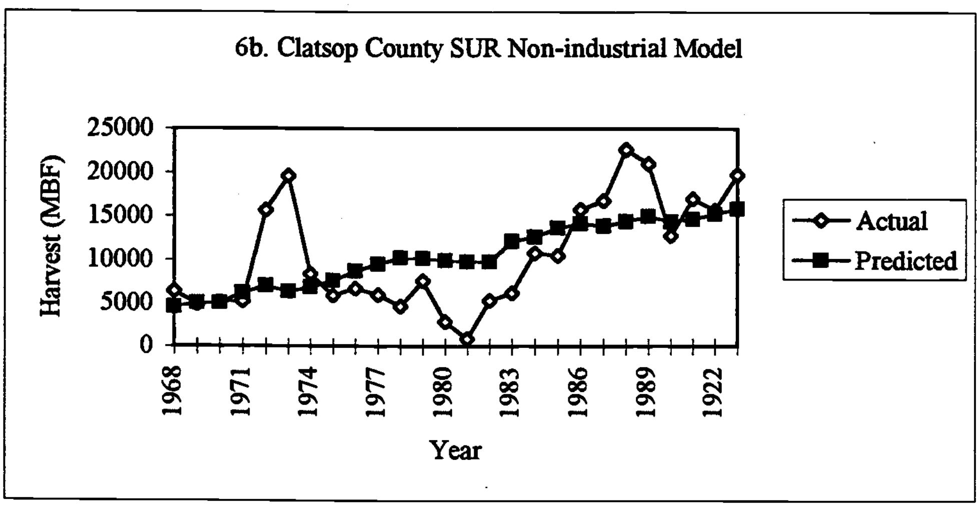


Figure 6a-h. Historical Simulation Plots: Non-industrial SUR Models





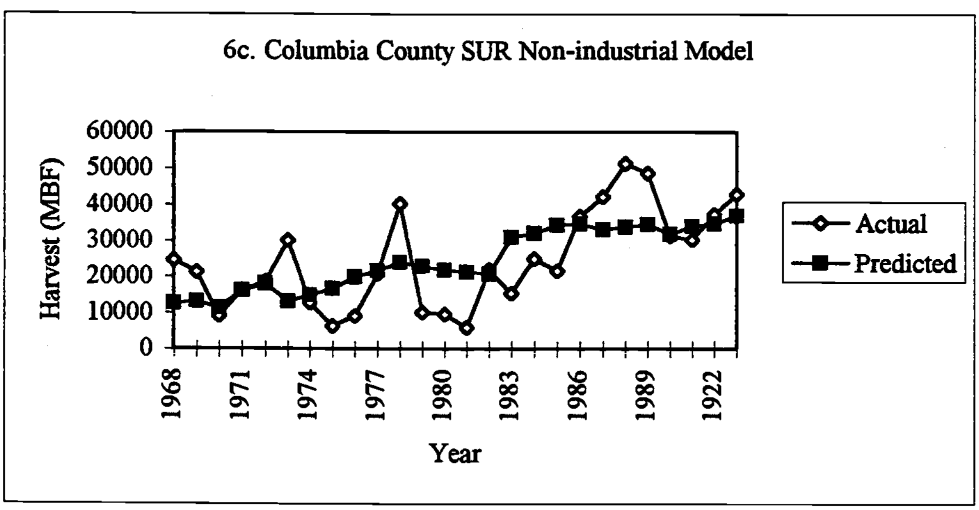
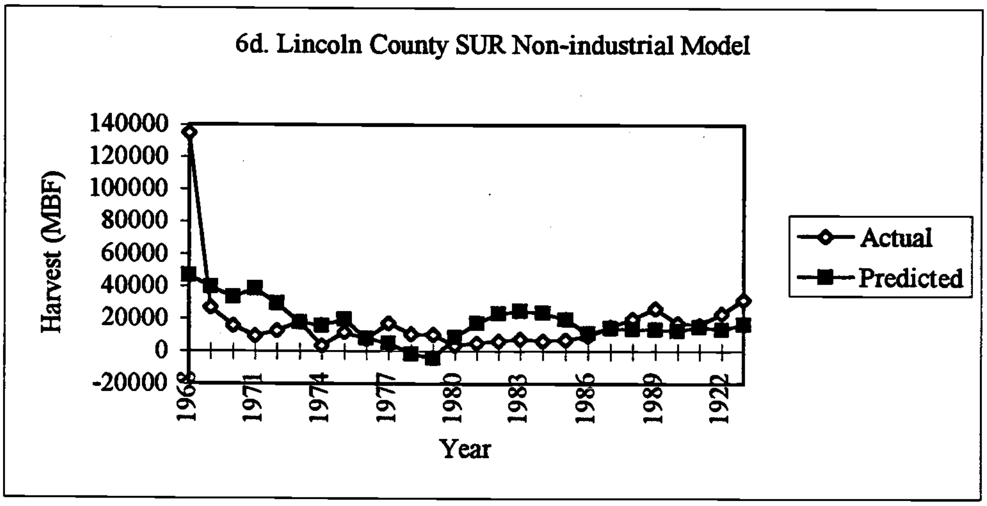
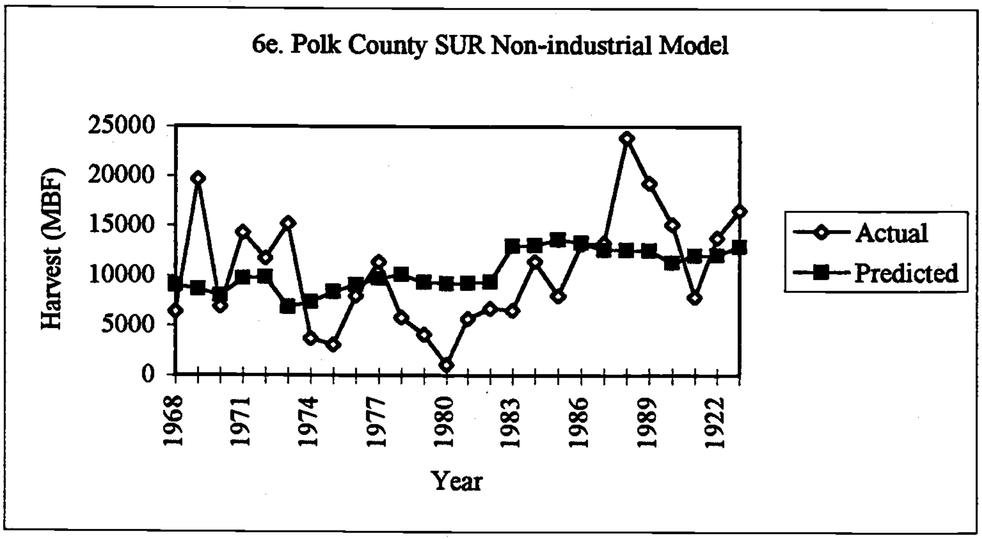


Figure 6. (Continued)





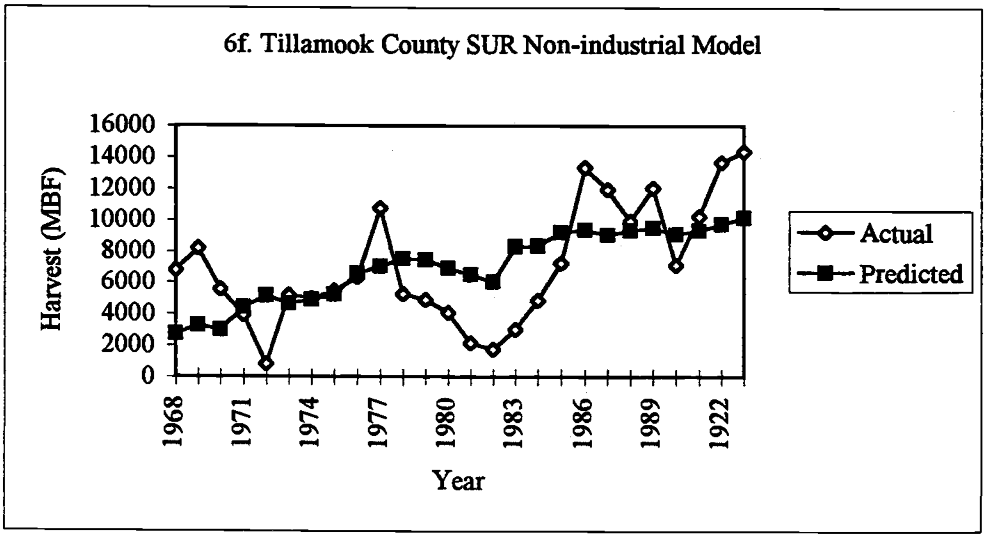
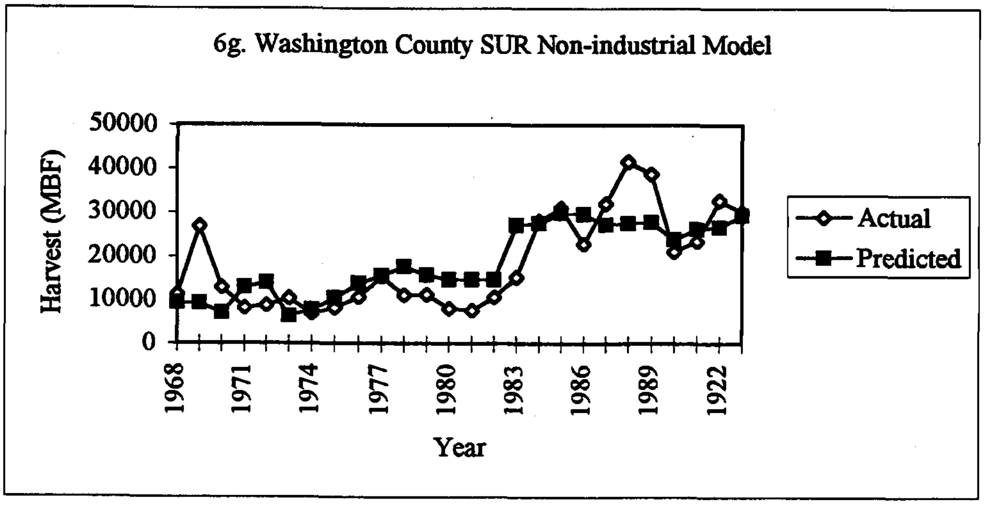


Figure 6. (Continued)



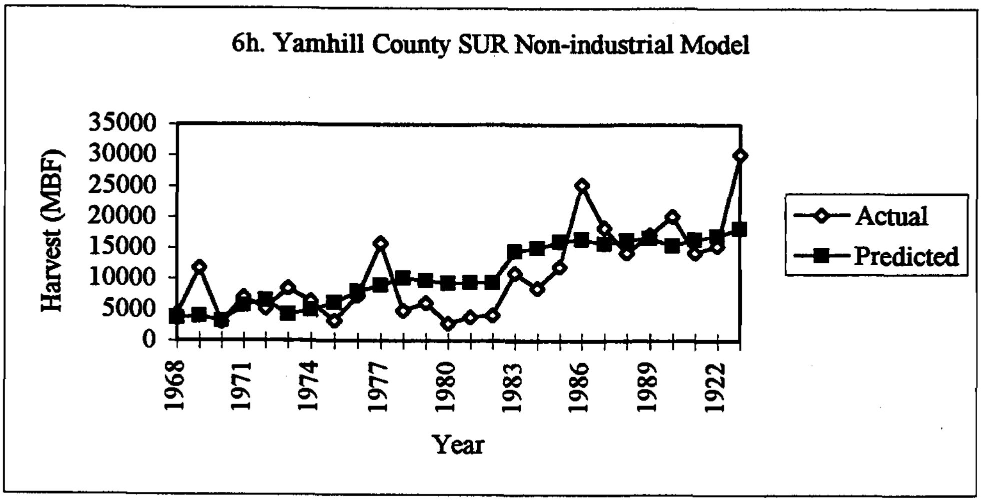


Table 15. Correlation of Inventory and Income Estimates: Non-industrial Model

County	Income/Inventory Correlation
Benton	.9519
Clatsop	.7561
Columbia	.6812
Lincoln	-.6497
Polk	.7386
Tillamook	.5390
Washington	-.7999
Yamhill	-.7188

Because the correlations between income and inventory indicate collinearity, an additional model was estimated using an approach to estimation used by Adams et al. (1992) where the ratio of harvest to inventory was modeled as a function of price and personal income. Just as in the original analysis, both OLS and SUR models were estimated. The test statistic:

$$\lambda = (26)(10.007) = 260.197$$

indicates that the SUR model provides more efficient coefficient estimates. The SUR modeling results are presented in Table 16.

Table 16. Additional Non-industrial Analysis: SUR Model

County	Constant	Price	Income
Benton	-135.203	0.203	0.0135
(std. error)	(49.768)	(.1344)	(.0043)
(p-value)	(.0123)	(.1444)	(.0049)
Clatsop	-395.511	.5304	.0275
	(96.915)	(.2185)	(.0086)
	(.0005)	(.0234)	(.0039)
Columbia	-168.661	-.048	.0251
	(70.749)	(.1321)	(.0083)
	(.0258)	(.7205)	(.0063)
Lincoln	598.945	.0061	-.048
	(174.39)	(.3168)	(.0192)
	(.0023)	(.9848)	(.0196)
Polk	-33.262	-0.0016	0.0099
	(53.088)	(.1094)	(.0060)
	(.5371)	(.9883)	(.1154)
Tillamook	-514.181	0.874	0.0137
	(189.54)	(.3447)	(.0203)
	(.0124)	(.0186)	(.1323)
Washington	-117.45	-0.1117	0.0165
	(51.061)	(.0963)	(.0044)
	(.0309)	(.2586)	(.0012)
Yamhill	-126.687	-0.0382	0.0173
	(41.977)	(.0769)	(.0047)
	(.0061)	(.6244)	(.0013)

The system weighted R-squared value for this model is .3611 thus the additional SUR model using the harvest to inventory ratio as a dependent variable has less explanatory power than the original model using only harvest as a dependent variable. However, for individual parameter coefficient estimates, the additional model provides, in many cases, more efficient and robust estimates. In the additional analysis for example, the coefficient on price had the expected positive sign in four of the eight counties and was significant at the .05 level in two of those counties. In the original analysis, all counties had unexpected negative signs on price and only one was significant at the .05 level. For the coefficient on income, the additional analysis provided estimates that were significant at the .05 level in six of the counties and had the expected positive sign in one county. The original analysis provided similar results with respect to signs, but only one of the estimates was significant at the .05 level.

Additional Analysis: Evaluation of Structural Changes

An additional question of interest concerning non-industrial landowners involves the possibility that recent changes in public timber supplies and other market forces have created structural changes in the market for non-industrial timber supplies. The possibility exists, for example, that some parameter coefficient estimates have changed in recent years as public timber supplies in the region have been reduced and local timber purchasers have increased procurement efforts, or non-industrial landowners may be responding to market signals differently as prices and inventories change.

In attempt to evaluate these possibilities, an additional SUR model was estimated for non-industrial landowners using a dummy variable approach. The model takes the form:

$$Y_{1t} = \beta_{11} + I_{1t}\beta_{12} + P_{1t}\beta_{13} + PC_{1t}\beta_{14} + d_{1t}\beta_{15} + \varepsilon_{1t}$$

Where: $d =$ 1 if t = 1984....1993
0 if t = 1968....1983

Thus if the estimated parameter β_{15} is found to be significantly different than zero, results would indicate that significant structural differences exist in the market for non-industrial timber between pre-1984 and post-1984 periods. Results of the dummy variable SUR model are presented in Table 17.

Table 17. SUR Dummy Variable Model Results

County	Constant	Price	Income	Inventory	Dummy
Benton	-1886.934	2.544	-0.507	58.334	16424
(std. error)	(44041)	(29.314)	(2.653)	(51.022)	(5916.443)
(p-value)	(.9662)	(.9317)	(.8502)	(.2658)	(.0113)
Clatsop	-20216	18.260	0.966	50.752	12945
	(18656)	(17.032)	(1.089)	(33.913)	(3470.28)
	(.2908)	(.2958)	(.3851)	(.1494)	(.0012)
Columbia	-8549.169	-11.865	1.611	42.603	19063
	(162230)	(39.529)	(2.775)	(475.196)	(7632.572)
	(.9585)	(.7670)	(.5677)	(.9294)	(.0209)
Lincoln	125788	-10.960	-13.993	178.787	12775
	(189184)	(88.965)	(5.756)	(1032.666)	(19395)
	(.5134)	(.9031)	(.0241)	(.8642)	(.5173)
Polk	-36359	4.113	0.108	246.347	11684
	(38273)	(19.091)	(1.039)	(177.928)	(3845.464)
	(.3529)	(.8315)	(.9179)	(.1807)	(.0062)
Tillamook	-19056	9.287	1.459	33.085	8419.927
	(10510)	(10.744)	(.666)	(18.997)	(2267.267)
	(.0841)	(.3971)	(.0400)	(.0896)	(.0013)
Washington	19488	-24.070	0.967	-49.434	19677
	(48985)	(21.936)	(1.317)	(233.640)	(4445.475)
	(.6948)	(.2849)	(.4711)	(.8345)	(.0002)
Yamhill	-20387	-7.982	1.260	72.197	9117.182
	(88358)	(18.804)	(1.465)	(429.810)	(3862.472)
	(.8198)	(.6755)	(.3996)	(.8682)	(.0280)

With the exception of Lincoln County, all of the dummy variables estimated in the SUR model were significantly different than zero indicating that structural changes in the region's market for non-industrial timber have occurred since 1983. Furthermore, the system weighted R-squared value of .6312 for the dummy variable model is greater than the R-squared value observed in the original SUR model for non-industrial landowners indicating that the dummy variable model has greater explanatory power that the original model.

Additionally, signs observed on several individual parameter coefficients in the dummy variable model conform with those expected by the theoretical model used in the study. Four of the counties showed the expected positive sign on the price coefficient which, in the original SUR model, exhibited unexpected negative signs. Signs on the coefficients for growing stock inventory also showed improvements over those observed in the original analysis. With the exception of Washington County, all of the counties had the expected positive sign on inventory in the dummy variable model, whereas in the original SUR model five of the counties had unexpected negative signs.

The positive sign observed on all of the dummy variable coefficients suggests that non-industrial landowners in the study counties exhibited a higher propensity to harvest timber after 1983. This corresponds with the observations of Adams et al. (1992) who observed similar structural changes for non-industrial owners in western Washington after 1983.

Discussion

The objective of this study was to develop timber harvest relations for a local market in western Oregon using a set of error-related economic relations. The model would provide a demonstration of an attempt to model timber harvests at the local market level where modeling efforts are often characterized by a shortage of adequate data, locally imperfect markets, and landowners with non-economic objectives. This approach assumes that landowners in spatially contiguous local markets are faced with similar forest, economic, and social conditions when making the harvest decision. Under such circumstances, a set of error-related economic equations may provide more precise estimates of supply/harvest relationships than traditional estimation methodologies. To fully evaluate the adequacy of this approach, three primary questions need to be addressed.

1. Should each sample of data for the counties in the study region be treated separately and individual harvest functions estimated separately for each county?
2. Because the counties in the study region have many characteristics in common, are the equation errors for each county contemporaneously correlated and, if so, can this information be used to develop more precise harvest relations?
3. Should samples of data for each county in the study region be combined into a common harvest function?

For industrial landowners, ordinary least squares estimation provides models with moderate to good explanatory power. Between 50% and 82% of the variation in county-level harvests was explained when counties were modeled individually. In most cases, the coefficients estimated for parameters in the individual models showed expected signs and were significantly different than zero. In the majority of instances where unexpected signs were observed, the coefficients were not significantly different than zero.

For the non-industrial landowner models, ordinary least squares estimates for the individual counties provide poor to moderate explanatory power. Between 6% and 59% of the variation in harvest is explained by the individual models. In addition to poor explanatory power, the non-industrial models showed signs on parameter coefficients that were contrary to theoretical notions. All of the models displayed negative signs on price, and only one of the coefficients was significantly different from zero indicating that non-industrial landowners in the study region are not price responsive. Several of the models also displayed unexpected positive signs on income, although for each of these counties, the coefficient on income was not significantly different than zero. The same pattern was found for the coefficient on the inventory parameter with unexpected negative signs in five of the eight models, and three of those five being insignificant at the .10 significance level.

Estimation of both the industrial and the non-industrial models using SUR indicates that improvements in the efficiency of the parameter coefficient estimates can be obtained using a contemporaneously correlated error structure. Additionally, because the test for contemporaneous correlation indicates that significant contemporaneous correlation does exist between counties for both the industrial and non-industrial models, the parameter coefficient estimates which incorporate contemporaneous correlation must, necessarily, be more efficient than those obtained by ordinary least squares. This conclusion is particularly true for the non-industrial landowner model where significant improvements over OLS were observed with the SUR model. Thus the results of this study indicate that more precise estimates of industrial and non-industrial timber harvest relationships for local markets can be obtained using an error-related model structure.

When the industrial models were estimated using seemingly unrelated regressions, an improvement in efficiency was observed on at least one parameter coefficient in each county. Similar improvements in efficiency were found for the non-industrial SUR model with at least one coefficient improvement in each model. Additionally, two coefficients that were insignificant at the .10 significance level using OLS, the income parameter coefficient for Clatsop and Polk counties, became significant at that same level when estimated using SUR to estimate the non-industrial model.

Estimation and testing of the restricted models for both landowners indicate that there is insufficient evidence to suggest that the coefficient vectors are the same across counties. This suggests that the influence that the variables have on harvesting decisions differ between counties in the region, therefore the “unrestricted” SUR models provide more precise estimates of timber harvest in the study region. This finding is likely due to differing sizes of landowner holding between counties, the location of processing facilities, or differing landowner objectives between counties.

Historical simulations of the SUR models indicate moderate predictive capability. However, a weakness of the historical simulations is that the models were not tested for predictive ability with data other than those used in the estimation process. Such a test would allow a better evaluation of the stability of the estimated parameter coefficients. Reserving sufficient data from the available time series however would have worsened the already critical small sample problems in estimation.

Observations: Industrial SUR Model

The lack of previous county-level harvest modeling efforts makes direct comparison of the results of this study difficult. However, some comparisons can be made between the results of this study and those of previous work with respect to signs on estimated coefficients, and with respect to how well the results satisfy *a priori* expectations.

For the industrial landowner model, the negative sign found on the coefficient for discount rate in all counties except Columbia County, is consistent with the findings of Robinson (1974). However, these findings are also contrary to those expected from the theoretical model used in this study. That is, one would expect harvests to rise as interest rates rise due to the increased capital holding costs associated with higher interest rates. Thus the results of this study imply two possibilities for the role of discount rates in determining harvest levels: first, that discount rates do not play a significant role in determining industrial timber harvest in the study region, or secondly, that the proxy variable used in this study does not adequately represent the true discount rates that landowners apply when making harvest decisions. Both possibilities are supported by the fact that the coefficients observed on the discount rate variable were not significantly different than zero for Benton, Polk, Tillamook, or Yamhill Counties, regardless of sign.

An additional explanation for the negative sign on the discount rate variable coefficient is that industrial landowners may be responding to changes in interest rates indirectly through final product prices. For example, as interest rates decline one would expect an expansion of the housing market and a subsequent increase in lumber prices. Industrial owners thus would increase harvests in response to the price of finished goods rather than reducing harvests in response to lower capital holding costs.

The coefficients estimated for price had the expected positive sign in four of the eight counties. Similar positive relationships were found for the Douglas-fir region by Robinson (1974), the Pacific Northwest (west side) by Adams and Haynes (1980), for the State of North Carolina by Daniels and Hyde (1986), and for Southern softwood pulp and sawlog markets by Newman (1987). Results of the present study are, however, somewhat inconclusive with respect to the role of price. For example, of the four counties with the expected positive sign, only Lincoln and Tillamook had coefficients that were significantly different than zero. Thus the results of this study suggest that price, as defined by the proxy variable used, plays a minor role in determining industrial harvests in the study region. This may indicate that industrial landowners in the region base stumpage values on finished good prices and mill input requirements rather than export log prices as assumed by this study. Reinhardt (1990) suggests that wood processing firms integrate "upstream" into timberland ownership to avoid holdup risk by other suppliers once the firm has invested location-specific capital in the form of a mill. Under such circumstances industrial timber harvests would be set according to mill input requirements and to avoid the risks associated with purchasing stumpage from other suppliers. A further explanation for the lack of price responsiveness by industrial landowners is the traditional presence of public timber supplies. Industrial owners may schedule harvests to satisfy mill input requirements and then opportunistically harvest public timber supplies in response to log price fluctuations.

The positive sign observed on the coefficient for growing stock inventory, for all counties except Lincoln County, satisfy *a priori* expectations from the theoretical model used in this study. That is, as growing stock inventories increase, a resulting increase in harvest volume occurs. In addition, each of the coefficients was observed to be significantly different than zero at the .05 level. These results coincide with those of Adams (1977) and Adams and Haynes (1980) for the Douglas-fir region. Thus the implication of this study is that the level of growing stock inventory plays a large role in determining harvest by industrial landowners in the study region.

For counties with the expected positive signs, price elasticity estimates are slightly higher than those observed in previous studies for industrial landowners (Table 18.). The inventory elasticity estimates for this study have the expected positive sign consistent with other studies, but in general are higher than those observed by others. The observed negative signs on all of the discount rate elasticity estimates, except in Columbia County, are consistent with the findings of Robinson (1974) but inconsistent with those of Adams et al. (1992).

Table 18. Industrial Landowner Elasticity Estimates

County/Study	Price	Inventory	Discount Rate
Benton	.536	.461	-.197
Clatsop	.015	1.694	-.469
Columbia	-.965	2.469	.169
Lincoln	.600	-.019	-.638
Polk	-.167	1.153	-.055
Tillamook	.711	3.895	-.84
Washington	-.061	2.187	-.361
Yamhill	-.299	4.434	-.151
Adams & Haynes (1980)	.26	1.00	
Adams et al. (1992)	.27	1.83	2.84
Newman (1987)	.55*	.39*	
Robinson (1974)	.11*		-.42*

*All owners

In summary, the results of this study suggest that harvests by industrial landowners in the eight county study region are influenced primarily by the level of growing stock available for harvest. Price appears to play a secondary role, however the presence of public timber supplies and the need to satisfy mill input requirements regardless of price may tend to confound the role that price plays in determining harvests. Interest rates appear to play a minor role in determining harvests. Elasticity estimates for variables with the expected signs on coefficients compare favorably with other studies.

Observations: Non-industrial SUR Model

The observed negative sign on the price variable indicates that non-industrial landowners in the study region do not respond to price signals in the expected positive manner. In each of the counties, price is either negatively correlated or is insignificant at the .05 confidence level. These results are similar to those of Tuazon (1992) who observed negative signs on price for non-industrial landowners in California. Adams and Haynes (1990) also found declining non-industrial harvests in western Oregon despite rising prices. Several explanations exist for the negative price response of non-industrial owners including non-economic management objectives, poor market information, or poorly defined markets due to the presence of public timber supplies. Strong conclusions regarding the relationship between harvests and price however cannot be drawn from the results of the present study since only one of the coefficients was significant at the .05 level.

Only one of the coefficients observed on the income variable was significant at the .05 level. All of the other observed coefficients were not significantly different than zero and in four cases had an unexpected positive sign. These results and those of others, suggest that the role of income in determining non-industrial timber harvests is indefinite. The counties with negative signs on the income coefficient - Benton, Lincoln, Polk, and

Washington - coincide with the findings of Tuazon and are compatible with the theoretical model used in this study. However, the positive signs observed on income for Clatsop, Columbia, Tillamook, and Yamhill Counties are also supported by the findings of Cleaves and Bennett (1995) who found higher rates of harvest participation among non-industrial landowners in western Oregon with higher personal incomes. A possible explanation for this dichotomy may be that per capita income provides a poor proxy variable for personal income. That is, per capita income likely includes both income derived from timber harvests and income derived from other sources, therefore collinearity may exist between harvest and income. An alternative would be to use only non-timber income in the analysis. The availability of this data however is unknown.

Coefficients on growing stock inventory in the non-industrial model presented similarly mixed results. Coefficients for Benton, Clatsop, Columbia, Polk and Tillamook Counties had unexpected negative signs, however all were significant at the .05 significance level. The coefficients for Lincoln, Washington, and Yamhill Counties had the expected positive sign and were significant at the .05 level, except in Lincoln County.

The negative signs on the price coefficient observed in the original SUR model result in negative signs on elasticity estimates for all non-industrial landowners (Table 19.) For counties with the expected positive sign on inventory, elasticity estimates are generally higher than those observed by Newman (1987) for all landowners, and by Adams and Haynes for non-industrial landowners. With the exception of Lincoln County, counties with the expected negative sign on income, elasticity estimates fall below that observed by Adams et al. (1992).

Table 19. Non-industrial Landowner Elasticity Estimates

County/Study	Price	Inventory	Income
Benton	-.780	-.674	-1.037
Clatsop	-.349	.623	.623
Columbia	-.734	.477	.477
Lincoln	-.721	-8.311	-8.173
Polk	-.679	3.440	-.410
Tillamook	-.439	-.652	1.259
Washington	-1.249	10.973	-.042
Yamhill	-.788	19.632	.403
Adams & Haynes (1980)	.06	1.00	
Adams et al. (1992)	.78* 1.04**		-4.41
Newman (1987)	.55***	.39***	
Robinson (1974)	.11***		

*<1984
**>1984
***All owners

An analysis of the possibility of collinearity between income and inventory indicated that there was significant collinearity between those variables in the non-industrial model. However a SUR model estimated with the harvest to inventory ratio as a dependent variable showed lower explanatory power than the original SUR model that did not address collinearity. Individual parameter coefficient estimates however were more robust in the model which addressed collinearity.

An analysis of the possibility of recent structural changes in the market for non-industrial timber suggests that significant structural changes have occurred since 1984. Results indicate that non-industrial landowners have shown a higher propensity to harvest since 1984, similar to the findings of Adams et al. (1992). An evaluation of the specific reasons for the increased propensity to harvest, such as increased price elasticities, would require additional analysis beyond the scope of this study however.

Policy Implications

Recent changes in public timber supplies have created an interest from the policy arena on the factors which determine private timber harvests. The results of this study therefore may provide valuable application when evaluating the harvest effects of various policies. The results of this study can aid policy analysis in three primary ways: First, the parameter coefficient estimates for individual variables can provide information to policy makers on how those individual variables would likely affect timber harvests from the two landowners. Secondly, for counties where high explanatory power was observed, the models provide a set of forecasting tools with which harvests can be forecast given values for the independent variables. Finally, the results of this study present a demonstration of a statistical methodology which can be applied to numerous situations where data are scarce and the structure of local markets is unknown.

Specifically, the results of this study have two significant implications for forest policy analysis for northwestern Oregon. First, for both landowners the level of growing stock inventory plays a significant role in determining timber harvest in the counties. Particularly for industrial landowners, where all of the coefficients on growing stock inventory were positive and significant at the .05 level, the volume of timber available for harvest plays a major role. The positive correlation infers that more volume will be harvested from these landowners as more timber is available for harvest. Policy analysts interested in evaluating the effects of policies on private timber supplies in the study region should therefore consider how the policies may affect levels of growing stock inventory.

The second major finding of this study important for policy analysis is the relative non-price responsiveness of non-industrial landowners. The negative signs on the coefficients combined with high standard errors suggest that non-industrial landowners do not consider price when making the harvest decision. A possible explanation put forth for this finding is that the traditional presence of public timber supplies resulted in poorly developed markets for non-industrial timber and these landowners therefore receive little information concerning prices. With diminishing public harvests these markets should become more well developed as the processing sector seeks out new sources of raw materials. Policy analysts should, however, evaluate forest policies which affect non-industrial landowners with this history of poorly defined markets in mind.

Conclusions

Traditional approaches to estimating timber harvest and supply relationships have emphasized ordinary least squares, or systems of equations approaches. These approaches have considerable appeal when applied to large-scale markets due to their ability to produce precise estimates and, in the case of simultaneous equations, establish the "feedback" relationships inherent in most economic systems. For smaller markets however, alternative statistical methods may be needed. The results of this study demonstrate that the use of a single equation model estimated using seemingly unrelated regressions provides more precise estimates of timber harvest at the county level than does ordinary least squares. In addition, for non-industrial landowners, this approach provides greater explanatory power than simultaneous equations approaches have shown in previous studies. This approach allows the development of local timber harvest relationships to be developed with the data needs and simplicity of ordinary least squares, yet improves on OLS estimates by making better use of the minimal amount of data typically available for local markets.

Although individual parameter coefficient estimates in some of the models, particularly in the non-industrial models, show signs that are contrary to theoretical assumptions and have high standard errors, the results of this study nevertheless demonstrate that the precision of timber harvest relations can be improved using a contemporaneously correlated error structure. This has particular importance when trying to estimate timber harvest and supply relations for local markets where the actions of individual landowners are magnified, there is a general lack of adequate data, and theoretical notions do not always hold true. Under such circumstances, any improvement in model precision is a welcome development.

Several steps could be taken to possibly improve both the OLS estimates and those developed using SUR. First improvements in the availability of data that is specific to local markets would likely lead to models greater explanatory power, more efficient estimators, and greater predictive capability. For example, a limitation of this study is the use of export log prices as a proxy for stumpage values in all counties. This ignores across-county differences in log production costs such as logging costs, transportation costs, or the integrated nature of most industrial landowners. All of which affect derived stumpage values. Additionally, for many landowners, export prices may not adequately reflect stumpage values due to poor market information, timber quality, or the need to supply mills and thus export prices may not be a satisfactory proxy variable. A more realistic approach would be to use county-specific time series data for actual stumpage prices. Unfortunately, for most local markets these data are nonexistent or difficult to obtain.

Further improvements in local modeling efforts could be made, particularly for non-industrial land owners, by re-specification of theoretical models. The utility maximization model used in this study for non-industrial harvest appears to have limited predictive capabilities at the local level. The model assumes that non-industrial landowners will vary their harvests according to price, growing stock inventories, and personal income. In reality harvest from these landowners may be a function of several other factors including the procurement efforts of local mills, the need for immediate emergency income, or landowner age. Recent anecdotal evidence also suggests that regulatory avoidance may play a role in rates of timber harvest from non-industrial landowners in western Oregon. An additional possibility, suggested by this study, is that non-industrial landowners respond to nominal prices and income rather than real prices and income.

The present net worth maximization model utilized in this study for industrial landowners appears to reasonably represent the harvest motivations of those landowners. Other factors however, may play a role in determining local harvest and thus may be worthy of consideration for inclusion in a theoretical model. These factors may include the need for short term cash flows to service debt, the availability of public stumpage supplies, or final product prices. The availability of the data at the local level, particularly in adequate time series, is unknown however.

The results presented in this study show higher explanatory power for non-industrial landowner harvest at the county level than the simultaneous equations approach, or the SUR approach, used by Tuazon in California. This suggests that the single equation approach may present a viable alternative for modeling harvests for these landowners.

The approach has the advantage of being simple yet presents explanatory power that is greater than that observed by earlier work using other methods.

For industrial landowners, no previous efforts have been made to model harvests at the county level using a simultaneous equations approach. The single-equation approach utilized in this study presents a viable alternative for modeling harvests for these landowners. However, given the more well-defined theory available for the harvest motivations of these landowners, it is conceivable that a simultaneous equations approach could work for industrial landowners at the county level. Such an approach would have an advantage over the single-equation error related approach used in this study in that the dynamic relationship between supply and demand could be evaluated. However, as discussed previously, a drawback to the simultaneous equations approach is the need to gather additional demand relationship data for each county evaluated in the analysis.

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Appendices

APPENDIX A: STUDY DATA

h1	h2	h3	h4	h5	h6	h7	h8	h9	h10	h11
12589	336544	82242	170119	744582	531988	165970	56501	105940	13865	11155
18174	246637	78400	153599	802104	449764	193301	48586	135827	12180	7840
34991	276466	86139	321029	660937	567665	139598	41825	112467	5215	11803
37948	350671	50158	406379	695322	623261	128418	47982	179172	13321	13026
15608	227901	66575	375799	625042	559088	88699	41813	101595	1405	14516
61978	144174	80591	326732	536262	541706	88299	39343	124033	6800	9363
48038	118299	57481	268871	591620	401893	96423	57699	140973	25965	15946
46952	183468	89866	318470	621255	479727	177905	54000	101722	14933	34162
47568	202887	93001	266556	615499	392246	147264	57766	134860	10123	34568
37040	138541	89045	280371	797822	328004	158340	49197	135911	9213	13747
46336	150126	132351	287308	665617	324304	186531	63920	142002	10739	23906
33592	177532	127094	210127	676384	369380	99185	60893	142556	18489	21266
26502	135838	97513	190350	729556	309605	105914	58321	115914	13701	25517
34265	127537	90518	203183	598577	315894	65404	64894	101757	11031	30815
34701	120371	135777	248975	694122	488718	108020	87628	83161	19675	37663
37969	130858	166589	191367	677539	444651	120401	84232	85733	25085	38287
36080	102823	172919	231306	646848	414599	117091	56510	62069	34865	43690
45012	109273	188075	241388	636113	433606	124377	76453	43729	42576	45838
51795	110171	171516	269545	591435	454691	108455	98538	45810	37945	60809
57335	109376	204901	263047	471437	464156	111446	103533	55269	38348	40530
88610	109929	213945	232948	325008	467889	121384	118371	30103	31855	52333
91106	179172	207215	263553	338040	478362	148147	105429	36724	40973	73273
77314	100996	149865	236289	385500	434316	181710	80297	59194	51105	35917
57636	164439	153073	217463	385860	391163	226651	96623	90720	61100	61883
56718	165832	167026	223459	288368	360805	255761	93439	68970	50005	74768
60440	170982	138446	203847	328231	366801	221264	113035	58649	55057	55057

h12	h13	h14	h15	h16	h17	h18	h19	h20	h21	h22
20999	6399	24658	40394	67692	122329	135026	6396	6785	11295	4227
19162	4808	21245	19333	60295	36932	27225	19682	8181	26905	11778
17318	5090	9155	14605	33683	28044	15655	6904	5548	12959	3054
27814	5190	16328	10645	28356	30784	9648	14325	3947	8175	6999
24200	15720	18713	24529	83631	51404	12493	11767	820	8835	5201
30665	19631	30018	32928	51669	75266	18059	15234	5211	10355	8500
5796	8368	12796	24217	56708	94314	3660	3704	4982	6927	6387
2204	5844	6287	17511	42681	31849	11920	3074	5489	8255	3205
8577	6646	9228	19178	31075	48122	7634	7976	6323	10631	7300
26498	5918	20836	31687	28544	43093	17434	11385	10770	15327	15809
5900	4624	40255	33716	48169	33406	10690	5849	5284	11126	4847
8700	7573	10122	24363	20993	29672	10281	4103	4929	11312	6131
4820	2831	9751	12375	23501	15623	3743	1116	4082	8015	2834
6095	854	6031	14588	19478	13256	5117	5662	2158	7615	3829
5333	5256	22072	8637	39970	21449	6270	6733	1780	10646	4168
9552	6166	15475	6122	36411	38141	7685	6535	3018	15245	10925
13208	10782	24919	11575	32880	33320	6479	11432	4884	28224	8452
12750	10450	21727	15253	35692	46404	7094	7991	7244	31116	12009
19647	15775	36749	30268	38227	34477	9538	13169	13326	22844	25218
14280	16804	42184	23338	30854	46394	15029	13269	11952	32064	18313
25484	22660	51352	28608	45532	64229	19910	23936	9930	41639	14290
24339	21022	48719	51958	83095	75006	26258	19303	12013	38874	17208
19205	12756	31368	44045	62962	86599	17217	15165	7111	21174	20144
13654	17018	30341	37170	38294	61879	16122	7863	10239	23475	14323
16719	15687	37389	52573	75350	89341	23396	13813	13659	32909	15460
23148	19827	43020	62712	99238	97115	31784	16569	14348	30249	30249

pl	r1	r2	r3	r4	r5	r6	r7	r8	r9	r10	r11
215	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
238	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83
292	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
228	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11
233	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69
364	8.15	8.15	8.15	8.15	8.15	8.15	8.15	8.15	8.15	8.15	8.15
364	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87
345	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33	6.33
316	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24
311	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55
303	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94
352	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97
388	12.61	12.61	12.61	12.61	12.61	12.61	12.61	12.61	12.61	12.61	12.61
409	15.34	15.34	15.34	15.34	15.34	15.34	15.34	15.34	15.34	15.34	15.34
431	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
270	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88
283	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
270	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95
296	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49
351	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
368	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66
384	8.99	8.99	8.99	8.99	8.99	8.99	8.99	8.99	8.99	8.99	8.99
461	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
449	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87
463	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
445	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3

y1	y2	y3	y4	y5	y6	y7	y8	y9	y10	y11
8031	8864	8653	8536	8212	8569	8057	7847	7672	11392	8782
8328	9309	9118	8917	8710	9061	8579	8456	8203	11686	9198
8090	9434	8927	9017	8734	9009	8976	8422	8098	11241	9014
8449	9462	8979	8915	9127	9358	8850	8426	8769	11334	8924
8455	10131	9844	9808	10088	10025	9602	8792	9327	11711	9428
9216	10656	10528	10064	10224	10557	10170	10321	9821	12547	10451
9074	10792	10831	9871	10023	10293	10386	10056	9784	12738	10210
9180	10914	10438	9789	9700	10189	10249	9572	9693	12414	9981
10034	11519	10653	10605	10512	11041	11264	10294	10574	13172	10799
10359	11940	10799	11058	10796	11660	11558	9990	10740	13852	11197
10960	12236	11280	11646	11236	12132	12159	10474	10919	14552	11501
10884	12276	11497	11679	11246	12016	12307	10814	10989	14799	11769
10555	11690	11094	10421	10658	11089	11343	10351	10467	14207	11137
10307	11090	10543	9862	9851	10583	10753	9964	9903	13645	10776
10212	10628	9849	9680	9457	10007	10338	9641	9351	13127	10218
10756	10875	10152	10010	10229	10400	10765	9982	9896	13303	10543
11226	11254	10626	10273	10537	10827	10894	10253	9799	13920	10716
11284	11965	10804	10635	10589	11064	11296	10546	10308	14007	10712
11766	12557	11157	11362	11015	11435	11956	10837	10475	14373	11281
11919	12306	11210	11336	11000	11641	11656	10819	10332	14359	11362
12132	12658	11446	11165	11197	11924	11709	10977	10528	14667	11626
12572	13252	11820	11425	11327	12353	11787	11277	10571	15106	11884
12436	12825	11960	11346	11132	12186	11707	11277	10616	15335	11852
12202	12332	12057	11202	10876	11974	11656	11071	10476	14855	11704
12624	12703	12127	11361	11096	12265	11807	11228	10767	15076	11908
12607	12595	12153	11296	10974	12221	11718	11176	10716	15020	11855

i1	i2	i3	i4	i5	i6	i7	i8	i9	i10	i11
80	1035	510	1166	3179	1932	1033	263	431	139	205
91	1017	527	1163	3100	1907	1014	278	425	147	210
102	999	544	1161	3021	1882	996	293	420	155	214
113	982	561	1158	2942	1858	977	307	415	163	218
124	964	578	1156	2863	1833	959	322	409	171	222
135	946	595	1154	2784	1808	940	337	404	179	226
146	928	613	1151	2705	1784	922	352	399	186	230
157	910	630	1149	2626	1759	903	366	393	194	234
168	893	647	1146	2547	1734	885	381	388	202	238
179	875	664	1144	2468	1710	867	396	382	210	242
190	857	681	1141	2389	1685	848	411	377	218	247
201	839	698	1139	2310	1660	830	425	372	226	251
212	821	715	1136	2231	1636	811	440	366	234	255
223	804	732	1134	2152	1611	793	455	361	242	259
234	786	749	1131	2073	1586	774	470	355	250	263
245	768	766	1129	1994	1562	756	484	350	257	267
256	750	783	1127	1915	1537	737	499	345	265	271
267	732	800	1124	1836	1512	719	514	339	273	275
278	715	817	1122	1757	1488	700	529	334	281	279
289	697	834	1119	1678	1463	682	543	329	289	284
300	679	851	1117	1599	1438	663	558	323	297	288
311	661	868	1114	1520	1414	645	573	318	305	292
322	643	886	1112	1441	1389	626	588	312	313	296
333	626	903	1109	1362	1365	608	602	307	321	300
344	608	920	1107	1283	1340	589	617	302	328	304
355	590	937	1104	1204	1315	571	632	296	336	308

i12	i13	i14	i15	i16	i17	i18	i19	i20	i21	i22
450	289	314	687	682	620	217	185	287	246	223
436	279	313	667	676	620	219	183	277	247	224
421	270	311	648	670	619	220	181	266	249	225
407	260	310	628	664	619	222	180	255	251	226
392	250	308	608	658	618	224	178	245	253	227
378	241	307	588	653	618	226	176	234	255	228
363	231	306	568	647	618	228	174	223	257	228
349	222	304	548	641	617	230	172	213	259	229
334	212	303	528	635	617	231	170	202	260	230
319	202	301	509	629	617	233	168	192	262	231
305	193	300	489	623	616	235	167	181	264	232
290	183	299	469	617	616	237	165	170	266	233
276	173	297	449	611	616	239	163	160	268	233
261	164	296	429	605	615	240	161	149	270	234
247	154	294	409	599	615	242	159	138	272	235
232	144	293	389	593	615	244	157	128	273	236
218	135	292	370	587	614	246	155	117	275	237
203	125	290	350	581	614	248	153	107	277	238
188	115	289	330	575	613	250	152	96	279	238
174	106	287	310	569	613	251	150	85	281	239
159	96	286	290	563	613	253	148	75	283	240
145	87	284	270	557	612	255	146	64	284	241
130	77	283	250	552	612	257	144	53	286	242
116	67	282	231	546	612	259	142	43	288	243
101	58	280	211	540	611	260	140	32	290	244
87	48	279	191	534	611	262	139	22	292	244

APPENDIX B: SAS PROGRAMS

```
options nocenter nodate nonumber linesize = 100;

data run1;
infile 'harvest1.txt';
input h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11;

infile 'harvest2.txt';
input h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22;

infile 'price.txt';
input p1;

infile 'income.txt';
input y1 y2 y3 y4 y5 y6 y7 y8 y9 y10 y11;

infile 'discount.txt';
input r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11;

infile 'invent1.txt';
input i1 i2 i3 i4 i5 i6 i7 i8 i9 i10 i11;

infile 'invent2.txt';
input i12 i13 i14 i15 i16 i17 i18 i19 i20 i21 i22;

/*Industrial Model North Coast*/
proc syslin sur vardef = n;
bent:model h1 = p1 r1 i1;
clat:model h2 = p1 r2 i2;
colu:model h3 = p1 r3 i3;
linc:model h7 = p1 r7 i7;
polk:model h8 = p1 r8 i8;
till:model h9 = p1 r9 i9;
wash:model h10 = p1 r10 i10;
yamh:model h11 = p1 r11 i11;
run;

/*Restricted Model North Coast*/
proc syslin sur vardef = n;
bent:model h1 = p1 r1 i1;
clat:model h2 = p1 r2 i2;
colu:model h3 = p1 r3 i3;
linc:model h7 = p1 r7 i7;
polk:model h8 = p1 r8 i8;
till:model h9 = p1 r9 i9;
wash:model h10 = p1 r10 i10;
yamh:model h11 = p1 r11 i11;
srestrict bent.r1=clat.r2=colu.r3=linc.r7=polk.r8=till.r9=wash.r10=yamh.r11;
srestrict bent.i1=clat.i2=colu.i3=linc.i7=polk.i8=till.i9=wash.i10=yamh.i11;
srestrict bent.p1=clat.p1=colu.p1=linc.p1=polk.p1=till.p1=wash.p1=yamh.p1;
run;


proc syslin sur vardef = n;
bent:model h1 = p1 r1 i1;
clat:model h2 = p1 r2 i2;
colu:model h3 = p1 r3 i3;
linc:model h7 = p1 r7 i7;
polk:model h8 = p1 r8 i8;
till:model h9 = p1 r9 i9;
wash:model h10 = p1 r10 i10;
yamh:model h11 = p1 r11 i11;
stest bent.r1=clat.r2, clat.r2=colu.r3, colu.r3=linc.r7, linc.r7=polk.r8,
polk.r8=till.r9, till.r9=wash.r10, wash.r10=yamh.r11;

stest bent.i1=clat.i2, clat.i2=colu.i3, colu.i3=linc.i7, linc.i7=polk.i8,
polk.i8=till.i9, till.i9=wash.i10, wash.i10=yamh.i11;

stest bent.p1=clat.p1, clat.p1=colu.p1, colu.p1=linc.p1, linc.p1=polk.p1,
polk.p1=till.p1, till.p1=wash.p1, wash.p1=yamh.p1;

run;
```

```
options nocenter nodate nonumber linesize = 100;

data run1;

infile 'harvest1.txt';
input h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11;

infile 'harvest2.txt';
input h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22;

infile 'price.txt';
input p1;

infile 'income.txt';
input y1 y2 y3 y4 y5 y6 y7 y8 y9 y10 y11;

infile 'discount.txt';
input r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11;

infile 'invent1.txt';
input i1 i2 i3 i4 i5 i6 i7 i8 i9 i10 i11;

infile 'invent2.txt';
input i12 i13 i14 i15 i16 i17 i18 i19 i20 i21 i22;

/*Non-Industrial Model North Coast*/
proc syslin sur vardef = n;
bent:model h12 = p1 y1 i12;
clat:model h13 = p1 y2 i13;
colu:model h14 = p1 y3 i14;
linc:model h18 = p1 y7 i18;
polk:model h19 = p1 y8 i19;
till:model h20 = p1 y9 i20;
wash:model h21 = p1 y10 i21;
yamh:model h22 = p1 y11 i22;
run;

/*Restricted Model North Coast*/
proc syslin sur vardef = n;
bent:model h12 = p1 y1 i12;
clat:model h13 = p1 y2 i13;
colu:model h14 = p1 y3 i14;
linc:model h18 = p1 y7 i18;
polk:model h19 = p1 y8 i19;
till:model h20 = p1 y9 i20;
wash:model h21 = p1 y10 i21;
yamh:model h22 = p1 y11 i22;
srestrict bent.y1=clat.y2=colu.y3=linc.y7=polk.y8=till.y9=wash.y10=yamh.y11;
srestrict bent.i12=clat.i13=colu.i14=linc.i18=polk.i19=till.i20=wash.i21=yamh.i22;
srestrict bent.p1=clat.p1=colu.p1=linc.p1=polk.p1=till.p1=wash.p1=yamh.p1;
run;

proc syslin sur vardef = n;
bent:model h12 = p1 y1 i12;
clat:model h13 = p1 y2 i13;
colu:model h14 = p1 y3 i14;
linc:model h18 = p1 y7 i18;
polk:model h19 = p1 y8 i19;
till:model h20 = p1 y9 i20;
wash:model h21 = p1 y10 i21;
yamh:model h22 = p1 y11 i22;
stest bent.y1=clat.y2=colu.y3=linc.y7=polk.y8=till.y9=wash.y10=yamh.y11;
stest bent.i12=clat.i13=colu.i14=linc.i18=polk.i19=till.i20=wash.i21=yamh.i22;
stest bent.p1=clat.p1=colu.p1=linc.p1=polk.p1=till.p1=wash.p1=yamh.p1;
```