A HEDONIC COST FUNCTION APPROACH TO AGRICULTURAL LAND PRICES

By

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ABSTRACT

Since Sherwin Rosen's paper on implicit markets and hedonic functions, there has been an increase in the application of hedonics theory. These applications have almost exclusively dealt with consumer choice and the implicit consumer demand for attributes. The methodology usually entails the two stage procedure of initially obtaining implicit prices from the hedonics function and then using these prices as dependent variables in a system of bid functions.

In this thesis, a system of bid functions for land attributes is derived from a Generalized Leotief cost function of the British Columbia dairy industry. These bid functions were estimated with land characteristics data from records of dairy land transactions. The proposed paper provides several interesting extensions to the present applied work in this area. The application of duality results in the specification and derivation of bid functions provide an important improvement in existing methodology since economic structure can be improsed and consistency of derivation can be obtained. Also, despite its popularity in consumption analysis, the application of hedonic theory in production and the derived demand for inputs have not been addressed.

Two main results are discussed in the thesis. The first concerns identification of cost function parameters (and therefore the dual production technology) through the system of bid functions in the absence of input quantity data. The second result is that in the context of land attribute choices in agricultural production, the question of endogenous and exogenous implicit prices are important concerns as some implicit attribute prices are determined by non-production related factors. It is shown that linear homogeneity of attributes in the hedonic function is a necessary condition for exogenous implicit prices.

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CHAPTER I

INTRODUCTION

An important development in the economic literature has been the hedonics approach to economics or the theory of implicit markets. Pioneered by the works of Becker (1965), Lancaster (1966) and Muth (1966), the theory suggests that an economic agent's desire for a good is not based on the good itself but on the utility derived from the attributes or characteristics which comprise it. This approach is appealing in that it can explicitly account for quality differences in goods, an area not addressed in the conventional literature. Also, even though one good is comprised of several characteristics, the same attributes may be included in different goods. The approach can therefore account for the demand of many seemingly unrelated goods by suggesting what their demand is based on a desire for selected attributes.

An analysis employing such an approach possess certain problems which are not characteristic of the traditional economic analysis. The most obvious is that since the attributes themselves are not freely traded, no explicit markets exist thus no explicit prices for these attributes are observed. However, the characteristics are clearly implicitly traded which would result in implicit prices. Though widely used, the theoretical foundation of these hedonic functions were not clearly developed until the work of Rosen (1974) who suggested that the hedonic function is an envelope of an underlying system of bid and offer functions for the attributes. It was also in the same article that he suggested an empirical procedure which could model the structure of the demand and supply of these attributes for a particular good. This has led to a host of empirical studies which employed his procedure with its main application in consumer demand. The methodology entails a two stage procedure of initially obtaining implicit prices from the hedonic function and then using these prices as dependent variables in a system of bid functions.

Despite its wide range of application in consumption analysis, the specification and derivation of bid functions in the literature has been lacking in consistency and structure. Bid functions have traditionally been simple in its specification with its derivation being void of important structural implications with respect to the underlying utility function and the optimization procedure. Specifically, the recent application of duality theory in economics which highlighted the need for more structure in the specification of demand functions have been ignored in the traditional bid function analysis.

Another neglected area is the application of hedonic concepts to production or more specifically to factor demand. Just as utility functions can be expressed in attributes, so can the production function of the firm. The resulting derived demand would analogously be for attributes rather than for the good itself. Such an approach can provide a host of revealing comparative static results of the firm and may provide a better understanding of the production technology.

The main focus of this thesis is an attempt at extending the application of hedonic theory to analyze the factor demand decisions of the firm. Issues such as the consistency and economic implication of bid function specifications will be addressed in the context of duality and flexible form analysis. Specifically, the demand decisions regarding the land input in agricultural production will be the input of focus.

Due to the important role which land plays in agriculture, there has been much research into the behaviour and determinants of agricultural land prices. Land value have been related to numerous factors among which includes the total farm asset values (Melichar 1979), sociological factors (Alonso 1981), landowner characteristics (Barnard and Butcher 1971) and expected future output prices (Chavas and Shumway 1981). The diversity of land quality and the fluctuation in land prices provide a natural avenue to apply our model of the firm. To be specific, the production technology and land purchase decision of dairy farmers in British Columbia will be analyzed in this study. Dairy production in British Columbia can be aptly characterized by cost minimization behaviour since output, and in some sense prices, is regulated by the market share quota system. Monthly land transaction data, input prices and output levels will be used to specify a cost function of the industry from 1970 to 1977. An interesting policy issue can be addressed in this study. In 1973, the agricultural land reserve program was established to preserve land for the sole purpose of agricultural production. This measure was deemed necessary because the competing land use problem between the urban and agricultural sector had reached a critical level. Needless to say, such restrictive land measures would cause adjustments in the land market thus knowledge of the effects of the program on agriculturé's bid for land is needed in understanding the total effect of such a program.

It should perhaps be noted at the outset that the issue of land value is complicated and its determinants are quite diverse. No claim is therefore made as to suggest that the proposed approach addresses all the issues relevant to land value. It is only suggested that this exercise can perhaps provide another method of analyzing land demand in the context of agricultural production.

1.1. Objectives

There appears to be a lack of application of hedonic concepts for the case of factor demands in production. Just as in the conventional hedonic consumer demand analysis, it may be instructive to apply the theory of implicit markets to the input attribute choices of the firm. Since the basis of implicit market studies in consumer demand theory revolves around the system of bid and offer functions, the application in the production context will centre around the derived demand functions for the attributes.

The objective of this thesis is to derive a system of bid functions based on cost minimizing behaviour of the firm. The system must be consistent with the hedonic theory as well as modern production concepts. The area of application will be the land input in agricultural production. Since the demand for land services in agricultural production is a derived demand, the implicit demand for its attributes can therefore be seen as being also a derived demand.

Specifically, the land attribute bidding behavour of the B.C. dairy industry will be analyzed. It is hoped that this exercise would provide us with interesting insights of some of the conventional production and hedonic concepts. It is also hoped that this analysis can reveal interesting information with regards to the attribute choices of the dairy farmers in B.C.

1.2 Plan of thesis

The plan of the thesis is as follows. A review of the hedonic literature and its various application is contained in Chapter II. Chapter III provides the theoretical development of the model used in this thesis. The choice of the empirical or econometric model is outlined in Chapter IV. This Chapter contains a section on the first stage hedonic function specifications and a second section describing the cost function to be used for estimation. Data is discussed in Chapter V while Chapter IV contains a discussion of the empirical results obtained and its interpretation in the context of the dairy industry in B.C. Particularly important is section 6.3 which captures an important finding of this thesis. This section is followed by conclusions and summary in Chapter VII.

CHAPTER II

REVIEW OF HEDONIC LITERATURE

Some of the earlier contributions to the hedonics theory or the characteristics approach to consumer theory have been Becker (1965), Lancaster (1966) and Muth (1966). Their basic contention was that the household is a production unit which produces activities from physical goods. The utility of these households are subsequently functions of these activities and not of the goods themselves. Households are then assumed to maximize their utility subject to the budget constraints for goods as well as a transformation function which relates the activities to the goods. The recognition that the conventional consumer theory does not encompass the possibility of new goods or changes in the quality of existing ones and ignores the value of consumers' time leads to the development of the household production theory. The household production theory addresses the quality concerns by noting that even though a single good would likely embody numerous activities, the same activities might well be produced by a large number of goods. For example, a car as well as a boat could have in common prestige and transportation activities.

The crucial element of this approach is the transformation function which expresses the goods in terms of the activities. An application of this approach invariably results in determining the relationship between the activities (which are in many cases non-quantifiable) and the physical goods. This approach has been analyzed further by

Lucas (1975) and its applicability to production has been explored by Archibald and Rosenbluth (1978).

Though the theoretical development in this area is advanced, the procedure has not lent itself to empirical application with the exception of King (1976). Other applications which use the hedonic concept have basically centered around the hedonic function, a function which relates the price of a good to its characteristics. Griliches (1971) employed this approach to derive a price index for automobiles. Lucas (1977) also utilized the hedonic function to explain the wage rates of workers by including variables reflecting the characteristics of the workers as well as the attributes of the particular occupation involved. In the context of land values, estimation of hedonic functions have been a well used tool.

It was not until the work of Rosen (1974) that an explicit theory regarding attributes of goods was developed. The hedonic function was shown to be the envelope of a system of bid and offer functions. The bid function can be viewed as the amount the consumer would be willing to bid for a particular attribute. Similarly, the offer function reflects the price at which the producer of the good would be willing to sell the characteristic. Bid functions are derived from utility maximizing consumers and offer functions are from profit maximizing producers where the utility and profit functions of both agents are expressed in terms of characteristics. Assuming equilibrium in the implicit characteristics market, the bid and offer prices are equal with the hedonic function being the envelope of these two interactions.

The nature of Rosen's model demonstrates the general departure of the characteristics approach with that of the conventional. Since the attributes are not freely traded, one has to assume that they are implicitly traded which will result in implicit prices for these attributes. The implicit prices are not observable thus some assumptions are required in order to relate the free trade of a good with the implicit trading of its inherent attributes. Rosen showed that the commonly used hedonic function is the link between the price surface, which is observable in the market, and the implicit prices of the characteristics, which is not.

In the same study, Rosen proposed an empirical procedure to investigate systematically the bid, offer and hedonic function. The suggested method was a two stage procedure whereby the first stage entails the duplication of market information by estimating a hedonic function. The gradient of the estimated function is assumed to be the implicit prices. The implicit prices are then calculated and used as the dependent variable in the second stage where a system of bid and offer functions are specified. The bid functions have as its arguments the characteristics as well as bid function shifters such as income of the household. Similarly, the offer functions have profit function parameters which affects the production cost of the characteristics producing firm.

Since Rosen's work, there have been numerous applications of his approach. Harrison and Rubinfeld (1978) analyzed the willingness to pay for clear air using housing market data. The choice to purchase a house was assumed to be based on the consumer's desire for the housing characteristics which includes the quality of air. Implicit prices for clearn air were obtained from the hedonic function. These prices were interpreted as a reflection of the consumer's willingness to pay for less air pollution. The bid price functions for clear air were then estimated to explain the effects of bid function shifters on the consumer's bid function.

Witte, Sumka and Erekson (1979) also applied this approach to the housing market. A quadratic hedonic function was estimated for four different housing regions. A system of linear bid and offer functions were estimated simultaneously using the calculated implicit prices as dependent variables in the system. Although reasonable results were obtained, their study has been criticized. Brown and Rosen (1981) questioned the procedure on identification grounds. They criticized the linear nature of the bid-offer functions and showed that structural parameters of the second stage are exactly determined by the first stage parameters. Epple (1981) addressed the error specification of their application.

Quigley (1980) looked at two implications with regard to the utility function and its relationship to the hedonic function. First, if the consumer preferences were prespecified, what restrictions are imposed on the market wide hedonic function. Second, the converse case of having the hedonic function determined by some best fit criteria, what restrictions would this impose on the utility function. For the former case, it was shown that pre-specified consumer preferences create only weak restrictions on the hedonic structure of market prices. In the latter case, the issue becomes one of identification of utility contours with nonlinear constraints. Quigley suggested that even the weak condition of homotheticity of preferences is not required for identification. His findings were subsequently applied to housing demand data.

Other applications of the hedonic approach includes Spady (1976) where the characteristics of the trucking industry's output was analyzed. A cost function was specified which was a function of input prices and output. The output variable was then replaced by a function which reflects the quality of the output. Share equations of the translog specification were estimated and information regarding the long and short run properties of the cost structure of the trucking industry were obtained.

Goldman and Grossmen (1978) applied the hedonic concept to investigate the demand for pediatric care. A utility function of the parents was assumed which is a function of their child's health. A child's health function is specified to be a function of the number of visits, quality per visit and other variables. Maximization of the utility function, which incluces the health function subject to the time and budget constraints resulted in demand equations for quality and the frequency of visits. These equations were estimated and information pertaining to the effects of quality of visits on the consumer were obtained.

Despite the many applications in the hedonics area, it is only recently that researchers have suggested the systematic integration of the hedonics theory with the modern flexible form dual approaches. Flexible form analysis based on duality results can in general provide more insight into the production technology while imposing economic structure on the modelling procedure.

An interesting analysis of the quality issue in the context of modern cost and production theory was provided by Berndt (1982). In his work, an analysis is made of the theoretical justifications of the various methods for introducing input attributes into convention cost and production studies. This was done in the context of a translog cost function. Factors of production were assumed to be augmented by quality adjusting indices which were defined to be functions of the input attributes. Two scenarios based upon the indices were considered. The first was labelled the "simple repackaging hypothesis" which suggests that the augmentation factors are only functions of the relevant input characteristics. The "variable repackaging hypothesis" suggests that the indices are functions of the characteristics as well as the input prices. Functional forms for the indices under the two hypothesis were specified and substituted into the translog cost function. Consistent cost share equations for the physical inputs were subsequently derived which included the vector of attributes. As suggested by the author, this approach has the potential of supplying a host of extremely revealing comparative static results with respect to the interaction of physical inputs and their attributes. Inferences with regards to technical change and capital formation were also proposed. Although the idea of introducing input attributes into the cost function is not new (Wills, 1978), Berndt's work provides a valuable theoretical foundation in the consistent integration of quality variables in the dual flexible form analysis. However, the problem of deriving a system of bid functions using duality theory was not addressed. In particular, the decision choice of the producing agent with regards to inputs and their attributes has not really been analyzed. His study, however, highlights the need for further research into the possibility of merging the two bodies of literature into one unified model.

CHAPTER III

THEORETICAL MODEL

Consider an aggregate single output per unit of land production technology which is represented by

$$y = f(x, h_1) \qquad (1)$$

where y is the output level,

x is an mx1 vector of non-land physical inputs and

h_1 is an kx1 vector of production related land characteristics.

It is assumed that this technology possesses the usual regularity conditions with respect to its arguments for a well-behaved technology. That is,

(i) $\nabla_x f(x,h_1)>0, \quad \nabla_{h_1} f(x,h_1)>0$

(ii) the Hessian of the function f is negative definite.

where $\nabla_x f$ is the gradient or the vector of first partial derivatives of f with respect to the components of the vector x.

Although the conventional production analysis does include certain attributes such as the size of the parcel, the suggested specification can be seen to be an extension of the conventional case since the proposed model is not only a function of the usual non-land inputs but is also a function of a host of production related land characteristics including size. Characteristics or attributes of this variety can include the drainage quality of land, the fertility level of the soil, or the slope of the land. Concavity in h_1 suggests that diminishing returns apply to these production related land attributes. It is not unrealistic to suggest for example that the output capacity of a parcel of land increases with drainage until a situation arises whereby excess water drainage may become a detriment as in the case of porous or sandy soil.

The aggregate firm is assumed to have the following cost structure:

$$C = w_1^T x + w_2(h_1, h_2) \tag{2}$$

where C is the total cost,

w_1 is an mxl vector of non-land input prices,

h_2 is an nxl vector of non-production related land characteristics and

w_2 is the unit price of land and is a function of h_1 and h_2.

The firm employs a unit of land thus w_2 is the unit cost of the parcel. The characteristic space of the land input is separated into two sets: a set for production related attributes, h_1 and attributes which do not directly affect production but does however affect the price of the parcel, h_2.

Land attributes of the h_2 category would include factors such as the distance from and the population of a nearby centre. In the case of population, an increase in the population of a nearby community would in general result in the increase of land values. Population growth would however unlikely increase the productivity of a nearby farm.

In general, the attribute list of $w_2(.)$ must include characteristics which reflect the desirable aspects of a parcel from an agricultural production standpoint. These are the production related attributes of h_1. On the other hand, since the parcel is also desired by the non-agricultural production sector, the attributes of land reflected by this demand must also be represented. Since the equilibrium price of a parcel is the result of the marginal valuation of each competing agent, the attribute list must reflect both sectors in order to avoid a misspecification of $w_2(.)$.

Although this distinction in the attribute list is necessary in the cost structure, the same arguments are not valid for the production function as f is a technological relationship between inputs and outputs. Therefore, f would only be a function of h_1, the land attributes which would directly affect the production process.

One may argue that all characteristics has certain effects on the production technology. For instance, the distance to market could alter the production process through changes in input prices due to transportation cost and therefore affecting his profit. On the other hand, factors such as soil fertility and cultivation capabilities of agricultural farmland would have a more direct effect on the production process as compared to distance. Production characteristics will therefore be defined to be factors which directly affect the production process and non-production attributes will be those whose effects are indirect. The concept of direct and indirect characteristics was employed by Griliches (1971) in his analysis of automobile quality.

Returning to the cost structure, it can be seen that the unit price of land function is the conventional hedonic price function for land whereby the price of a unit parcel is expressed as a function of its attributes. Given the cost schedule and the production function, a cost function can be described as:

$$C(w_1, h_2, y) \equiv \min_{(x, h_1)} \{ w_1^T x + w_2(h_1, h_2) : y \leq f(x, h_1)\} \qquad (3)$$

Before deriving the comparative statics of this cost function, it is important to consider the behavioural implications of the above relationship. The cost function states that given a target or a pre-determined level of output, the producer would maximize profits by minimizing cost to achieve the level of output. Thus the output level is basically pre-determined. Also implied is a single output production process.

As we are modelling the dairy sector, both assumptions are applicable. The dairy industry is one of the more heavily regulated industries in agriculture. A program of quotas is used which dictates the amount of milk that can be produced and sold at a subsidized price with any excess sold at a lower price. Since the target output levels of milk producers are determined by the size of the quota for each farm, the level of output is basically pre-determined. An avenue exists in some jurisdictions, notably in B.C., whereby quotas can be traded. To some extent, the output level is not fixed but at least in such industries, given the high price of quotas and some imperfections in the capital markets, the cost of increasing output levels is more than in comparable unregulated industries without output restrictions.

It should be noted that the use of a cost function does not necessarily require the firm to have a fixed level of output. Cost minimization subject to a predetermined output level is a behavioural assumption on the part of the firm. If the farming decisions are based on a perceived target output level, the application of the cost function is still valid, even if the target output level changes. The stronger assumption of a fixed output level can be seen to be an extreme case of this weaker condition. Due to the nature of the industry, the second assumption of a single output technology is also valid as dairy farmers in general do not indulge heavily in other farming activities other than milk production. It is also assumed that competition prevails in the non-land factor markets and therefore dairy farmers are price takers in these input prices.

As mentioned in the literature review, the idea of introducing input characteristics into the cost function is not new. However, its introduction in this model is unique since cost minimization is performed with respect to x and h_1. When a farmer makes a land purchasing decision with respect to the land attributes, it would seem unlikely that such choices are made independently of the other non-land inputs. It is not unrealistic to suggest that a certain degree of interaction is present between the land characteristics and other factors of production. For instance, a farmer's decision to purchase a parcel with a lower level of cultivation ease that he desires is implicitly substituting the extra amount of his labour required to work the parcel for the land attribute. The actual substitution would be determined by changes in relative input prices which in this context are the changes in the opportunity cost of the farmer's labour, his wages, and the changes in the implicit prices of the cultivation attribute. It is important to note that the above decisions are strictly contained within the cost minimization choice framework and are independent of the utility function and personal preferences of the farmer.

The attribute choice of the farmers provide an alternative interpretation for the seemingly arbitrary separation of the attribute list into two subgroups. When the farmer embarks on a land purchase decision, he is faced with a menu of land attributes available for each parcel. Ignoring the indivisibility of the attributes for now, he would choose a subset with which he feels is crucial to his farming operation. In the aggregate, this would result in a subset of attributes which are choice variables in the land purchase decisions of the farmers. The implicit prices for the desired attributes would be determined by the market forces exerted by the bidding farmers while the prices for the other attributes will be determined by the marginal valuation of other bidding agents. In this context, the previously defined production related attributes would be those whose prices are determined by the bids of the farmers. This interpretation has strong implications with regards to the price determination process for the attributes and will be further discussed at the latter part of this chapter.

Returning to the cost function, the LaGrangian expression associated with this function is:

$$L = w_1^T x + w_2(h_1, h_2) + \lambda[y - f(x, h_1)] \qquad (4)$$

where λ is the LaGrange multiplier.

It is assumed that the aggregate firm chooses the optimal level of non-land inputs and relevant land characteristics to minimize cost given the cost structure and the production technology of the firm. That is, the expression is minimized with respect to x, h_1 and λ resulting in the following set of first order conditions:

$$\nabla_x L = w_1^T - \lambda \nabla_x f \tag{5.1}$$

$$\nabla_{h_1} L = \nabla_{h_1} w_2 - \lambda \nabla_{h_1} f \tag{5.2}$$

$$\frac{\partial L}{\partial \lambda} = y - f(x,h_1) \tag{5.3}$$

Equation (5.1) is the familiar relationship between the input price and the marginal product of the input. Equation (5.3) has the interpretation of λ being the shadow price of an extra unit of output or in our case, the aggregate supply price of milk. Equation (5.2) is similar to Equation (5.1) since it relates the price of an input to its marginal product. From Rosen, we know that the gradient of the hedonic function is the vector of implicit prices of the corresponding characteristics. If we let the implicit price of production characteristic i be P_i where $1 \leq i \leq k$, component i of (5.2) becomes

$$P_i = \frac{\partial w_2}{\partial h_i} = \frac{\partial f}{\partial h_i} \tag{6}$$

This condition reveals certain aspects of the model which are empirically important.

Consider two elements of the production related land characteristic vector h_1. Call the two elements h_i and h_j where $1 \leq i,j \leq k$. The corresponding ratio of the two first order conditions become:

$$\frac{P_i}{P_j} = \frac{\partial w_2/\partial h_i}{\partial w_2/\partial h_j} = \frac{\partial f/\partial h_i}{\partial f/\partial h_j} \tag{7}$$

Equation (7) is the familiar tangency condition for minimal cost production whereby the slope of the budget line (the ratio of the implicit prices) equals to that of the isoquant (the marginal rate of substitution of h_i for h_j). If the hedonic function, $w_2(.)$ was assumed to be linear as is in the case of several hedonic function studies, the ratio P_i/P_j will be a constant. It is known that in the estimation and identification of demand functions, relative price variability is essential to trace out the indifference sets. In this case, if a linear hedonic function is adopted, such variability is not present thus making it impossible to identify the contours of the production technology. Even if we were not interested in identifying the factor demand of a production characteristic, fixed relative implicit prices is a strong assumption to impose on factors of production attributes (Quigley 1980). Since in general, fixed relative prices is an unnecessary restriction, a non-linear hedonic function is used in this study. For such a case, the problem becomes one of a constrained optimization problem with non-linear objective function and non-linear constraints. The conditions for optimality and identification of such a problem is outlined in Intrilligator (1971). In the context of hedonic functions, Quigley (1980) and Edlefsen (1981) have addressed this issue.

From the first order conditions, optimal values for x and h_1 can be obtained which are functions of w_1, y and h_2:

$$x^*(w_1, h_2, y) \tag{8.1}$$

$$h_1^*(w_1, h_2, y) \tag{8.2}$$

where the stars denote optimal values.

Substituting these values into the objective function, we obtain the aggregate cost function which represents the least cost method of producing the output level given exogenous input prices and non-production characteristics.

$$C^*(w_1, h_2, y) = w_1^T x^*(w_1, h_2, y) + w_2(h_2, h_1^*(w_1, h_2, y)) \qquad (9)$$

It is known that under general regularity conditions, the cost function is dual to the production function and completely characterizes the relevant information of the technology (Diewert 1974)[1].

Upon application of the envelope theorem or Shephard's Lemma (Shephard 1953) to equation (9) the following comparative static results can be obtained:

$$\nabla_{w_1} C^* = \nabla_{w_1} L = x^*(w_1, h_2, y) \qquad (10.1)$$

$$\nabla_{h_2} C^* \quad \nabla_{h_2} L = \nabla_{h_2} w_2(h_1, h_2) = P_2(w_1, h_2, y) \qquad (10.2)$$

where P_2 is an nx1 vector of implicit prices of the n non-production land attributes.

Equation (10.1) is the derived demand function of factor inputs which is a function of its own price, output level and the non-production land characteristics. Equation (10.2) states that the change in the optimal cost level of the aggregate firm if an extra unit of h_2 is employed would be to increase the cost by the implicit price of h_2. These prices are functions of $\hat{w}_1$, h_2 and y. Equation (10.2) provides a system of inverse demand functions whereby its price is expressed as a function of the commodity and other factors. This relationship when interpreted as a bid function reveals an interesting implication of the general model with respect to h_2.

The bid function for h_2, and therefore the cost function, are not functions of the implicit price of the production characteristics. This is not at all surprising since the farmers when making their land purchasing decisions implicitly choose the characteristics that they would like their parcel of land to have. Thus the production characteristics are choice variables and therefore endogenous. Since the price of the parcel is a function of these characteristics, the implicit prices are in fact endogenous and therefore would not appear in Eq. (9). This is similar to the case of a monopsonistic firm where the firm is not a price taker and the input prices are endogenously determined (Varian 1978, pp.74).

Endogenous implicit prices are purely the result of the non-linear objective function (Edlefsen). Consider the conventional case when prices and quantities are expressed in linear combinations. The gradient of this function with respect to the inputs is the vector of input prices and can be interpreted as being the shadow price of the inputs. Due to linearity it has a vanishing Hessian. For this case, the shadow prices can be interpreted to be parametric and therefore exogenous. This is consistent with the price taking assumption in the input market for cost function studies. However, if we consider the case of a non-linear objective function such that there exists a non-vanishing Hessian, it follows that the gradient of such a function cannot be treated parametrically since it is a function of the arguments. The shadow prices are therefore endogenous. In the present model, this translates to endogenous implicit prices.

There can be a case however, under imperfections in the characteristics market, whereby some of the production characteristics of a parcel are not optimally chosen. For instance, since a given piece of land is a fixed composite of its attributes, cases may arise whereby a producer may purchase a parcel with a non-optimal level of one characteristic in order to have access to the attributes which he feels is crucial to his farm. Because of the indivisibility, the purchaser may have to be content with such an arrangement. Given this situation, the implicit price of these non-optimum characteristics will be determined by other conditions and is therefore exogenous. This departure from the conventional concept of choosing the optimal factor input is a consequence of the indivisible nature of land attributes with respect to the parcel.

Pursuing the idea of an exogenous implicit price, we might ask what impliciations, if any, can we make with regards to the general hedonic function under such a scenario.

If we assume that both the vectors of characteristics are exogenous, the new cost structure C', would be very much similar to the conventional specification:

$$C' = w_1^T x + P_1^T h_1 + P_2^T h_2 \qquad (11)$$

where P_1 and P_2 are the corresponding exogenous prices. Since the hedonic function specification of (2) is expressed in general terms, an interesting exercise would be to see if we can say anything about the general expression. Recall that the original structure is:

$$C = w_1^T x + w_2(h_1, h_2) \tag{12}$$

Equating equations (11) and (12) and eliminating the non-land effects we have:

$$w_2(h_1, h_2) = P_1^T h_1 + P_2^T h_2 \tag{13}$$

Since P_1 and P_2 are implicit prices, they are defined as the gradient of the hedonic function. Realizing this, equation (13) becomes:

$$w_2(h_1, h_2) = (\nabla_{h_1} w_2)^T h_1 + (\nabla_{h_2} w_2)^T h_2 \tag{14}$$

This is the familiar Euler's theorem and the condition under which this holds is if w_2 is linear homogenous in its arguments. It can therefore be seen that a linear homogenous hedonic function would imply exogenous implicit prices. This can be a basis for a test of exogenous implicit prices since a test for linear homogeneity will give us this result. It should be noted that this test can also be used to determine whether a particular attribute belongs to the production or non-production subset of attributes since non-production related land characteristics have exogenous implicit prices.

In reality, however, it is seldom the case that all of the implicit prices are exogenous as in the above example. A more realistic possibility is that some of the production characteristics are optimally chosen and some are not thus resulting in a small subset of exogenous implicit prices. The analogous test for this case of testing for a small sub-group of exogenous prices requires stronger assumptions on the hedonic function.

In the context of this study, where an aggregate cost function is required, the possibility of a subset of characteristics not optimally chosen is unlikely even though such misallocations can occur at the individual farm level in the context of an imperfect characteristic market. However, if we assume that there are many buyers and sellers in the market for attributes, this is no longer a problem since even if an attribute is not optimally chosen, the market would assign to it a lower implicit price to reflects its level of undesirability. Therefore, this lower price would be endogenous. The assumption of a perfect market for characteristics will be kept and the presence of exogenous implicit prices will not be tested. The hedonic function used in this study will, however, be non-homogenous.

Referring back to the characteristic demand functions, it can be seen that several of the requirements of this study are met in that a system of demand equations is derived which is consistent with cost minimization behaviour and are functions of variables which are not determined at an ad hoc fashion.

Footnote

[1]A weakness of the proposed methodology in its present form is the lack of knowledge of the structural implications implicitly imposed on the production function as a result of prespecifying a nonlinear objective function. Specifically, since the cost and the hedonic function is prespecified, the duality results with regards to its dual production technology is somewhat unclear. This is purely a consequence of the introduction of a prespecified nonlinear function into the cost structure since the duality results for the usual linear case is well known. The comparative statics with regards to the substitute and output effect of the expenditure function has been well analyzed by Edlefsen. It was found that for a well behaved production function with convex level curves, the degree of substitutability of the attributes vary with the convexity of the level curves of the cost structure. It was also shown that the introduction of nonlinear constraints do not severly complicate the comparative static analysis and the usual results apply. Even though this result is appealing from an applied point of view, it does not explicitly provide evidence that the underlying production technology would pocess the appropriate regularity conditions. It is suspected that in order to derive specific properties of the production functions, a set of local duality results in the same vein as Blackorby and Diewert (1979) used in their paper to show continuity of the primal production function under certain conditions of the dual cost function would have to be derived. A more general approach would be to apply the results of Epstein (1981) in his description of generalized duality and integrability. Though this is clearly a serious concern with respect to the duality results, it is felt that the derivation of such duality results is beyond the scope of this paper.

CHAPTER IV

ECONOMETRIC MODEL

With the previous theory and assumptions described, this and the following sections will deal with the specification and estimation of such a model. In terms of estimation, the conventional two stage procedure will be used. The first stage entails the duplication of market information by fitting a market wide hedonic function. Implicit prices for both forms of attributes will be derived at this stage. The second stage entails the estimation of a system of bid functions which are consistent with cost minimization behaviour. These will be the bid functions for the non-agricultural production related attributes.since the cost function is a function of the input prices, the output level and the non-production related land attributes. Since quantity data of the other non-land inputs are not available, the factor demand equations will not be estimated with the system.

Model specification is dealt with in the first two sections of this chapter. The first section is concerned with the first stage specification and contains a discussion of some empirical properties which are required of the hedonic function in the context of this study. The second section will discuss the selection and the appropriate modification of functional forms for our cost function. The majority of these modifications are required as bid functions will be estimated as opposed to the usual factor demands. The addition of dummy variables to capture the effects of the agricultural land reserve program on production behaviour will also be discussed.

4.1 First Stage Model

To make the theoretical model operational, some measure of the equilibrium price of the characteristics is required. The method used will be to initially estimate a hedonic function from which the implicit prices can be obtained as described in the previous section. The question of functional form for the hedonic function arises and the issue of selecting the appropriate one has been widely investigated. In this context, the dominant forms used have been linear (Kain and Quigley 1970, King 1976), log, semi-log and double log (Griliches 1971, Dhrymes 1971). Best fit criterias were also used to address this issue (Brereton 1979, Quigley, 1980, Linneman 1980, Halvorsen 1981).

The basic requirement for the function relationship is that it be nonlinear and nonhomogeneous in the characteristics as suggested in the last section. For the present analysis, the hedonic function must also be sufficiently complex such that the resulting implicit prices will vary for different characteristics. The method of Box-Cox was used in several studies (Quigley, Brereton) to obtain implicit prices. Though the resulting functional forms will be nonlinear in the arguments, this technique is not totally applicable to the present case since variability between relative prices does not follow as demonstrated by the following result.

Consider the following Box-Cox transformation of the dependent variable (Zarembka 1974) as applied to an arbitrary hedonic function q with J characteristics.

$$q^{(\lambda)}=\begin{cases}\frac{q^{\lambda}-1}{\lambda} & \text{for } \lambda\neq 0\\ \log q & \text{for } \lambda=0\end{cases} \tag{15}$$

where $q^{(\lambda)} = \sum_{i}^{J} B_i h_i + e$ (16)

and
- q is the price of the commodity,
- h_i is characteristic i,
- B_i are the coefficients,
- e is the error term which is assumed to be normally distributed with constant variance and
- λ is a parameter which measures the degree of nonlinearity of the relationship.

Sum of square errors are minimized with respect to the parameters B_i and λ. Rearranging the terms for the case of $\lambda\neq 0$, eq (15) becomes

$$q = [\lambda(\sum_{i}^{J} B_i h_i + e) + 1]^{\frac{1}{\lambda}} \tag{17}$$

The implicit price of characteristic i is defined to be:

$$\frac{\partial q}{\partial h_i} = \frac{1}{\lambda}[\lambda(\sum_{i}^{J} B_i h_i + e) + 1]^{\frac{1}{\lambda} - 1} \cdot \lambda B_i \tag{18}$$

The ratio of the i^{th} and j^{th} implicit price will be:

$$\frac{\partial q/\partial h_i}{\partial q/\partial h_j} = \frac{B_i}{B_j} \quad \text{for } i \neq j \qquad (19)$$

That is, the variability between the two implicit prices is exactly determined by the ratio of their respective coefficients. Therefore, employing this approach would result in imposing a rather strong implicit assumption on the implicit prices. Along with price variability, the functional form selected should have cross terms among the characteristics to take account of the interactions between the attributes. In other words, the hedonic function should have a non-vanishing Hessian since the existence of implicit prices which are not functions of other attributes besides its own appears to be an unnecessary restriction. It appears that the necessity for price variability for each attribute and the need for cross terms would eliminate the majority of the hedonic functions presently employed in the literature.

Since there is no a priori theory to determine the shape of the hedonic surface, other than the linearity and homogeneity conditions stated in the last chapter, it would seem appropriate to select a function which is capable of providing a second order approximation to an arbitrary function while still providing price variability and cross terms for the attributes.

Following Witte, Sumka and Erekson, the following functional form will be used as it meets all our requirements:

$$w_2 = \alpha_0 + \sum_i^{n+k} \alpha_i h_i + \tfrac{1}{2}\sum_i^{n+k} \sum_j \alpha_{ij} h_i h_j + e \qquad (20)$$

where α_i's; α_{ij}'s are parameters and e is the error term and is assumed to be $e \sim N(0,\sigma^2)$. It can be seen that eg. (20) is quadratic in its arguments and is also non-homogeneous in its attributes. Since eg. (20) is also linear in the parameters, conventional OLS estimation techniques can be used to obtain parameter estimates.

One assumption of the error structure in the case of OLS application may however, not be totally valid. That is, the assumption that the data has sufficient range to assume a normal distribution about the mean. Since negative land prices are not possible, it is conceivable that the error term is not normally distributed but may be a truncated normal with the truncation level being 0. For such a case, the resulting distribution will resemble a normal distribution with its lower end deleted. This property of the data is conventionally labelled as the case of truncated samples or more generally, limited dependent variables and has its roots in low wage earning studies where negative wages are not observed. It has been shown (Hausman and Wise 1977, Goldberger 1973) that for the case of truncated samples, application of OLS will result in a downward bias of the parameter estimates. A maximum likelihood estimation technique was developed by Hausman and Wise, and modified by Quan and Kerr (1983), was initially used to address this problem. Maximization of the likelihood function requires the use of nonlinear optimization techniques which are subject to a high degree of numeric instability for the case of collinear data. As eg. (20) is quadratic and therefore would invariably contain cross terms, collinearity of the data is a real possibility. This was in fact the case when such a procedure was adopted for the hedonic function.

Highly unrealistic values as well as an indefinite information matrix were obtained. Various optimization routines were used with the same general result. For this reason, OLS was used to estimate the hedonic function. The problem of multicollinearity is still present but within the context of OLS, it is known that multicollinearity will bias the standard errors of the estimates upwards but the parameter estimates will remain unbiased (Johnston 1972). Also, the OLS procedures are not subject to the same degree of numeric instability as in the case of the maximization of a likelihood function. Since the purpose of this first stage is to obtain realistic estimates of the implicit prices for the second stage, application of OLS to collinear data is preferred to other estimation techniques such as Ridge regression where the resulting parameters are known to be biased. It will be assumed that the bias introduced by the possible truncation of the sample is small and will not affect the results significantly.

From eg. (20), the implicit price of the i^{th} characteristic will be calculated as:

$$\frac{\partial w_2}{\partial h_i} = \alpha_i + \alpha_i h_i + \frac{1}{2} \sum_{j \neq i}^{n+k} \alpha_{ij} h_j \qquad (21)$$

It should be noted at this stage that the estimation of a market wide hedonic function with real market prices results in parameter estimates which could reflect both the offer and the bid for the attributes. As in the conventional supply and demand analysis, identification becomes a relevant issue. It is for this reason that Rosen's proposed method entails the joint estimation of both the bid as well as the offer functions.

However, it is known that under certain market conditions, identification of the system of bid functions can be unambiguously determined (Berndt). The market for land characteristics can be viewed in the short run as being a second hand market. As in such markets, the supply is either fixed or inelastic. Market price fluctuations can therefore be only attributable to shifts in demand with the prices being strictly demand determined. Since it can be argued that the supply of agricultural land with particular attributes is inelastic, it is reasonable to assume that the implicit prices are bid determined thus eliminating the need for the joint estimation of the offer functions.

4.2 Cost Function Specification

For empirical estimation, a specific functional form is required for the cost function. A host of flexible functional forms have been developed (Diewert 1971, Christensen, Jorgenson and Lau 1972, Denny 1974). But due to the particular nature of our model, as well as data limitations, not all of them are appropriate. One requirement of the specification is the need for the inclusion of the vector of non-production characteristics. That is, unlike the conventional cost function which is a function of input prices and the output level, the hedonic cost function also includes land characteristics. Possible candidates are the variable cost or profit functions which have as one of its arguments fixed factors. However, even within this class, not all variable factor functional forms are applicable. The translog specification has been used in the context of variable cost functions (Christsen, Cummings and Schoech 1981). The actual estimation procedure invariably involves the calculation of factor cost shares which requires data on the physical quantities of all factors. Quantities of non-land factor inputs are not available in the data set.

One functional form which is feasible is the variable profit functional form as proposed by Diewert (1973). A variable profit function, in Diewert's notation, is defined as:

$$\pi(p;\nu) \equiv \max_u \{p^T u:\ (u;\nu)\varepsilon T\} \tag{22}$$

where p is the vector of prices (positive for input and negative for output),

T is the production possibilities set,

ν is the vector of fixed factors and

u is the vector of variable inputs and outputs.

The variable profit functional form is:

$$\pi(p;\nu) = \sum_i^I \sum_h^I \sum_j^J a_{ih}(\tfrac{1}{2}p_i^2 + \tfrac{1}{2}p_j^2)^{\frac{1}{2}}\nu_j + \sum_i^I \sum_j^J c_{ij}p_i\nu_j + \sum_i^I \sum_j^J \sum_k^J b_{jk}p_i\nu_j^{\frac{1}{2}}\nu_k^{\frac{1}{2}} \tag{23}$$

It has been shown (Diewert) that Eq. (23) is a second order approximation to an arbitrary function and can satisfy a host of conditions. Two conditions which are most relevant to the present study are the following homogeneity results:

(i) π is linear homogeneous in p_j, i.e., for every $\lambda>0$,
$\pi(\lambda p;\nu) = \lambda\pi(p;\nu)$ and

(ii) π is linear homogenous in ν, i.e., for every $\lambda\geq 0$,
$\pi(p;\lambda\nu) = \lambda\pi(p;\nu)$

A logical candidate for the hedonic cost function would be to use eq.(23) and substitute the subset of characteristics for the fixed factors. Though appealing, the resulting functional form is not altogether appropriate as certain modifications are required.

By substituting the input price w_i for p_i, replacing the fixed factor ν_j by characteristic h_j, and including the appropriate modifications, the following functional form is proposed:

$$C(w,h,y) = \sum_i^I \sum_m^I \sum_j^J a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{\frac{1}{2}}h_j + y\sum_i^I \sum_j^J c_{ij}w_i h_j^2 + \sum_i^I \sum_j^J \sum_k^J b_{jk}w_i h_j^{\frac{1}{2}} h_k^{\frac{1}{2}} + y\sum_i^I \sum_j^J d_{ij}w_i h_j^2 D \qquad (24)$$

An important departure of eq. (24) from eq. (23) is the addition of the square term of the characteristics in the second expression. This would violate the homogeneity condition of the function with respect to the characteristics. However, linear homogeneity in the input prices is preserved. Linear homogenous in the input prices suggest that as input prices are increased by a proportionate amount, the cost would also increase by this amount. This condition must be satisfied for any cost function. The same condition is not appropriate for the characteristics since if all characteristics in the cost function are increased by the same proportion, the total cost will not in general increase by the same factor. Total cost will be affected in some fashion as dictated by the hedonic function. In general, it is only under restrictive conditions of the hedonic function, namely linear homogeneous in the cost function attributes that the cost function will be homogeneous of degree one in these attributes.

Another modification is the need for the introduction of the output term in eq. (23) since the cost function is also a function of the output level. The method for its inclusion is in the same vein as Park's (1971) adaptation of the Generalized Leontief functional form.

A third modification is the inclusion of a dummy variable D. This would control for the effect of the agricultural land reserve program which was enacted within the period under investigation. The proposed method of including D would allow for the effects of the land reserve program on the input prices, the characteristics as well as on output. It will be shown later that its inclusion in eq (24) can control for the land reserve effect on each bid function as well as on the price flexibilities.

From eq. (24), the following results can be obtained:

$$\frac{\partial C}{\partial w_i} = \tfrac{1}{2}\sum_j^J \sum_m^I a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{-\frac{1}{2}} h_j w_i + y\sum_j^J c_{ij} h_j^2 + \sum^J \sum^J b_{jk} h_j^{\frac{1}{2}} h_k^{\frac{1}{2}} + y\sum_j^J d_{ij} h_j^2 D \quad (25.1)$$

$$\frac{\partial C}{\partial h_j} = \sum_i^I \sum_m^I a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{\frac{1}{2}} + 2y\sum_i^I c_{ij} w_i h_j + \tfrac{1}{2}\sum_i^I \sum_k^J b_{jk} w_i h_k^{\frac{1}{2}} h_j^{-\frac{1}{2}} +$$

$$2y\sum_i^I d_{ij} w_i h_j D \quad (25.2)$$

$$\frac{\partial^2 C}{\partial w_m \partial w_i} = -\tfrac{1}{4} a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{-1\frac{1}{2}} w_i w_m \sum_j^J h_j \quad (25.3)$$

$$\frac{\partial^2 C}{\partial h_k \partial h_j} = 2y\sum_i^I c_{ij} w_i + \tfrac{1}{2} b_{jk}(h_j h_k)^{-\frac{1}{2}} \sum_i^I w_i + 2y\sum_i^I d_{ij} w_i D \quad (25.4)$$

$$\frac{\partial^2 C}{\partial w_i \partial h_j} = \tfrac{1}{2}\sum_m^I a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{-\frac{1}{2}} w_i + 2yc_{ij}h_j + \tfrac{1}{2}\sum_k^J b_{jk}h_k^{\frac{1}{2}}h_j^{-\frac{1}{2}} + 2yd_{ij}h_jD \quad (25.5)$$

$$\frac{\partial^2 C}{\partial y \partial h_j} = 2\sum_i^I c_{ij}w_ih_j + 2\sum_i^I d_{ij}w_ih_jD \quad (25.6)$$

where I and J are the number of input prices and characteristics respectively. In the present study,

i, m = F, W, H, C

where F represents feed prices,

W is the wage rate,

H is the price of hay and

C is the rental price of capital.

j, k = M, D, P, V

where M is the month attribute

D is distance of nearest centre,

P is the population of the nearest centre and

V is the distance from Vancouver.

Equation (25.2) will provide the system of estimating equations. Equation (25.1) is the relationship of the effects on cost due to a change in input prices. These are the conventionally estimated derived demand conditions. The symmetry conditions of the cost function with respect to input prices will result in $a_{im} = a_{mi}$. These symmetry conditions have implications with regards to the structural derivation of the cost function. It has been shown by Hurwicz and Uzawa (1971) that if the Hessian matrix of the cost function is symmetric, then the system of derived demand conditions is integrable, that is, there exist an aggregate cost function and a production technology consistent with the optimizing procedure. Integrability of a cost function can be a testable hypothesis as in Binswanger (1979). In the present case, symmetry will be imposed as a maintained hypothesis since this will have the nice feature of imposing structure into the problem as well as reducing the number of free parameters.

Another set of normalizations which are useful and are imposed are:

$$a_{ii} = 0, \; b_{jj} = 0 \text{ and } b_{jk} = b_{kj}$$

These normalizations are required as without them, the resulting functional form would have parameters which are not identifiable.

Equation (25.5) describes the change in the implicit prices of the characteristics as a result of the change in the input prices. This will provide an avenue to analyze the effects of input price changes on the bid prices of the non-production characteristics. Equation (25.6) will record the effect on the bid prices due to a change in the output level. Since each of the above comparative static results differ from each observation, their values will be evaluated at the mean of the observations. Given the econometric model, we can not proceed to estimate the system of bid functions.

4.3 Estimation Techniques

Application of the envelope theorem to the cost function (24) will result in the following system of implicit price dependent bid functions:

$$P_j = \sum_i^I \sum_m^I a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{\frac{1}{2}} + 2y\sum_i^I c_{ij}w_ih_j + \tfrac{1}{2}\sum_i^I \sum_k^J b_{jk}w_ih_k^{\frac{1}{2}}h_j^{-\frac{1}{2}} + 2y\sum_i^I d_{ij}w_ih_jD \qquad (26)$$

for i, m = F, W, H, C and

j, k, = M, D, P, V.

where P_j is the implicit price of characteristic j from the first stage estimation. All other terms are as previously defined.

It is assumed that the explanatory variables are non-stochastic and that they also satisfy the usual rank condition. Each equation also contains an additive Tx1 vector of disturbances which has a zero mean vector with covariance matrix $\sigma^2 I$ where I is a TxT identify matrix with T being the number of observations. Let e_i be the disturbance vector for equation i. It is known that under these ideal conditions, application of OLS will result in BLUE estimates for each equation. OLS however implicitly assumes that all information relevant to each equation are present within the model. In the present case where a system of equations exist, the assumption of complete information may not be valid as the across equation errors may be correlated. If the errors are correlated, efficiency gains can be had by recognizing these relationships explicitly in the estimation procedure.

Let Σ be the covariance matrix of the system of equations where the diagonal contains the variance of each equation and the off-diagonals would contain the covariance of the different equation errors (i.e., element j, k of Σ for $j \neq k$ would contain $E(e_j e_k'))$. A simple test for across equation correlation would be to test the hypothesis that Σ is a diagonal matrix. If Σ is diagonal, this would suggest that no across equation correlations are present thus application of OLS would be appropriate. This can therefore be viewed as a test for the appropriateness of OLS.

A likelihood ratio test was used to determine whether Σ is diagonal. The restricted log likelihood function value was -2841.1 and is obtained by forcing Σ to be diagonal. -2 times the difference of this value and the corresponding value for the free case resulted in a value of 31.4. It is known that minus twice the logarithm of the likelihood ratio is asymptotically a Chi-square distribution with the number of degrees of freedom being the number of restrictions imposed in the restricted case (Theil 1971). Since $\chi^2_{95}(5) = 18.55 < 31.4$, the hypothesis that Σ is diagonal is rejected at the 95 percent confidence level.

Since we cannot reject that across equation correlation of the errors are present, the chosen estimator must address this interrelationship.

An estimator which takes this information into consideration and also allows for across equation restrictions of the parameters is Zellner's Seemingly Unrelated Regression (SUR) estimator (Zellner 1962, 1963 and Zellner and Huang 1962). Although the non-iterative SUR will fulfill the error structure as well as the parameter restriction requirements, it has been shown by Kmenta and Gilbert (1968) that if one iterates this estimator with the restrictions imposed at each iteration, the converged parameter estimates will in fact be asymptotically maximum likelihood. The iterative SUR will therefore be used in this study as it meets all the requirements as well as providing a relatively easy way to obtain maximum likelihood estimates.

Another source of efficiency gains would be to estimate the hedonic function jointly with the system of bid functions. This would be analogous to including the cost function into the estimation of the system of derived demand functions in cost function estimations. Efficiency gains in the cost context has been suggested by Green and Christensen (1976). However, for the present study where the bid functions have as their dependent variables relatively complex functions of the first stage parameter and variables, the joint estimation of the hedonic function with the bid functions would considerably complicate the estimation procedure. Therefore, the two stage procedure will be adopted.

CHAPTER V

DATA AND DATA CONSTRUCTION

In the first stage estimation, observations on land values and their corresponding land characteristics are required. Records of monthly sales of dairy farmland throughout British Columbia were obtained from the Farm Credit Corporation from January 1970 to December 1977. A total of 215 transactions were used. The characteristics of these dairylands which changed hands were:

(i) Price of the parcel of land in thousands of dollars.

(ii) Size of the parcel in acres.

(iii) Number of acres cultivated.

(iv) Distance of the parcel in miles to the nearest centre with a population greater than 500.

(v) Population of the nearest centre with a population greater than 500.

(vi) Distance from Vancouver in miles and

(vii) An index of the month which the transaction took place.

The price of the parcel was deflated by the Consumer Price Index in order to express the value in real terms. From the list, the size and the number of acres cultivated will represent the production characteristics with the remaining classified as land attributes not directly related to production.

Since the parameters estimated at the first stage play a very crucial role in the second stage, it is important that all relevant characteristics be present to minimize specification error. A casual survey of the variables suggest that non-production characteristics are reasonably well-represented. A potential source of left out variable bias may however be present for the production attributes as only two measures are used, size and the acreage cultivated. Depending on the level of detail, the list of attributes can be a rather lengthy one thus some errors from omitted variables is inevitable. However, Griliches pointed out that if the left out variables were separable from the included characteristics list and are constant over time, the left out variables will not pose a serious problem. The approach of using a small subset to represent the spectrum of characteristics is partially supported by Kain and Quigley. In their hedonic study of housing quality, a list of 39 attributes were compiled indicating the physical or visual quality of the bundle of residential services. Through factor analysis, it was shown that individual households evaluated residential quality in terms of several broad aggregates. Analogously, it is assumed that the two production characteristic measures are highly correlated with the omitted ones. It is important to note that since this study is designed to investigate bid function for nonproduction characteristics, the purpose of the production attributes are only to control for the effects of production characteristics in the price of land.

The parcel's total value was divided by the size of the parcel and multiplied by 1000 to obtain the price per acre of land in real dollars. Also, acres of cultivated land were expressed as a percentage of total acreage cultivated.

In the second stage model, observations on input prices and output levels are required. Four input prices were used; the price of feed, price of hay, wages and a capital term which includes capital, buildings and structure.

The feed, wage and hay price statistics are from the British Columbia Milk Board's Annual Reports. A price index of 16 percent dairy feed was used to reflect the price of feed. The price of alfalfa hay was obtained and is expressed in dollars per ton. Farm wages with board in British Columbia was used for the wage rate. These wages were expressed in dollars per month.

Rental rates of capital and structure were obtained through yearly figures on farm stock values of capital in British Columbia agriculture (Statistics Canada Cat. No. 21-003 Quarterly Bulletin of Agriculture Statistics), depreciation on machinery, repairs to buildings, and depreciation of building (Statistics Canada Cat..No. 21-003-P Farm Net Income) for the period 1971 to 1977. The corresponding values for 1970 were obtained by linear extrapolation from the 1971 values. This was necessary since the accounting system for these figures were changed in 1971. The depreciation figures take into account the declining value of capital as a result of its utilization. Building depreciations are based on farm buildings which includes the farm business share of the house or owner-occupied farms. Repairs to buildings are the estimated expense of cost associated with repairs and maintenance of farm buildings which include the farm business share of the farm house. The total value of farm stock in British Columbia reflects the replacement value of the stock of machinery and implements.

The rental rates of farm machinery and implements are obtained by the following formula:

$$R_m = \frac{r + \delta}{1 + r} V_m \qquad (27)$$

where R_m is the rental value of machinery and implements

r is the interest rate,

δ is the net depreciation rate (net of appreciation)

V_m is the total value of machinery and implements.

r is assumed to be a constant 6% for the period under investigation.

The net depreciation rate, δ is estimated by dividing the total machinery depreciation figures by the total farm capital stock. For the analogous measure for building and structure, the values of repairs to and depreciation of buildings were summed.

The output variable is measured in total value terms. Due to the present milk marketing system, each dairy producer can sell milk at a set price, as determined by a cost of production formula, up to a quantity as determined by each producer's quota. Sales of milk in excess of the allowable quota amount are possible but at a lower price. Total value of milk production of both quota as well as excess production were calculated for British Columbia (excluding Vancouver Island) and are expressed in price per litre. All value figures were subsequently deflated by the consumer price index. The results of using the above data in the econometric model can now be discussed.

CHAPTER VI

DISCUSSION OF RESULTS

With the estimation performed, the results of the estimates and their implications can now be discussed. The first section of this chapter will deal with the estimates of the hedonic function and the resulting implicit prices. Since a subset of these prices will be used as dependent variables in the second stage, it is quite important that they take on realistic values. The validity of all implicit prices will be discussed in this section. The second section of this chapter will discuss the estimates from the system of implicit price dependent bid bunctions. Results pertaining to the effects of input price changes on the bid prices for attributes will be evaluated. This will be followed by a discussion of the effects of the land reserve program on the implicit prices. An alternate interpretation of the bid function parameter estimates will be proposed at the end of this chapter.

6.1 First Stage

The estimated coefficients for the first stage model are presented in Table 1. An R-square value of .6841 implies that the model has captured a reasonable amount of total variation in land prices. An adjusted R-square value of .6385 indicates that a large number of irrelevant variables were not included. Significance at the 95% confidence level were obtained by 11 of the parameters while at the 90% level, 15 were significant.

TABLE 1

Estimates of the Hedonic Function
(t-ratios are in parentheses)

Variable	Coefficients	Variable	Coefficients
Month	-0.1112 (-.485)	(Month)*(Size)	-.096* (2.160)
Size	-28.917* (-4.357)	(Month)*(Cult.)	.298** (1.665)
Cult.	-60.018* (-2.103)	(Month)*(Dist.)	-.195 (-.941)
Dist.	-91.953* (-1.965)	(Month)*(Pop.)	-.018** (-1.458)
Pop.	3.599 (.932)	(Month)*(Dist.Van.)	.002 (.108)
(Dist. Van)	-10.335* (-2.418)	(Size)*(Cult.)	.157 (2.970)
Month^2	.196** (1.372)	(Size)*(Dist.)	.104 (.895)
Size^2	.105* (3.206)	(Size)*(Pop.)	.007 (.812)
Cult.^2	.316 (.955)	(Size)*(Dist.Van.)	.006 (.508)
Dist.^2	.793 (.642)	(Cult.)*(Dist.)	.697 (2.013)
Pop.^2	-.008** (-1.397)	(Cult.)*(Pop.)	.020 (.526)
$(\text{Dist.Van})^2$	.027 (2.695)	(Cult.)*(Dist.Van.)	.033 (1.089)
(Dist.)*(Pop.)	-.037 (-.442)	R^2 =	.6841
(Dist.)*(Dist.Van)	.087 (1.008)	$\overline{R}^2$ =	.6385
(Pop.)*(Dist.Van)	.049* (-3.054)		
Intercept	6115.5* (3.945)		

* significant at the 95% confidence level.
**significant at the 90% confidence level.

Due to the nature of the functional form used, it is suspected that a certain degree of multicollinearity exists. This would create an upward bias in the variance of the estimates and subseqently resulting in lower t-statistics. Even with this bias, the model in general still attained a reasonable number of significant variables.

The functional form, being quadratic in the arguments, provides coefficientes which are not, in themselves, easily interpretable. The purpose of this first stage estimation is, once again, to obtain meaningful implicit prices for the non-production related land attributes. These implicit prices were calculated for each of the six characteristics according to equation (21) of Chapter IV and are presented in Table 2. The expression for the implicit price of characteristic i is once again:

$$\frac{\partial W^2}{\partial h_i} = \alpha_i + \alpha_{ii} h_i + \tfrac{1}{2} \sum_{j \neq 1}^{n+k} \alpha_{ij} h_j \qquad (28)$$

Since these prices vary for each observation, summary statistics are also provided. Also, since the attributes are measured in such a way as to allow for both positive and negative effects on the land value, positive as well as negative implicit prices are possible.

The implicit price for month is $12.32 per acre. This result suggests that if a parcel of land was held for an extra month, factors which increase the land prices over time would raise the land value by this amount. On average, a parcel larger by one acre would decrease the price per acre by $8.91. Several circumstances can provide this result. One is the possibility of capital rationing. A scarcity of capital will result in a decrease in the demand for large plots of land and will therefore lower the per acre price of large parcels.

TABLE 2

Table of Implicit Prices

225 observations

Implicit price of	Mean	Std.Dev.	Min.	Max.
Month	12.318	7.938	-19.703	27.179
Size (acres)	-8.915	5.913	-23.432	26.224
Cult. (% of total)	3.663	11.384	-27.550	47.588
Dist. (miles)	-19.251	19.198	-68.629	56.216
Pop.	- 1.249	4.828	-20.498	3.756
Dist. Van. (miles)	-10.603	9.031	-36.053	6.777

A simpler explanation would be that the buyers simply want smaller size parcels. On average, an extra percentage of acreage cultivated would increase land prices by $3.66 per acre. This value appears to be quite small if one considers the purpose which this attribute serves in the hedonic function. Once again, the reader is reminded that the attributes size and cultivation are the two aggregate production characteristics which hopefully provide an adequate representation for the spectrum of land attributes relevant to production. For this reason, it may be slightly misleading to interpret these results only in terms of size and cultivation. Since the implicit prices of the non-production characteristics are the variables which will be hopefully explained, it is only necessary that these two attributes control for the production characteristic's effect on land value.

The two distance variables, the distance from a nearby centre and the distance from Vancouver, basically captures the locational influence on land prices. Average implicit prices for the distance from the nearest centre and from Vancouver are -$19.25 and -$10.60 respectively. That is, a parcel of land a mile further away from a nearby centre would be cheaper by $19.25 per acre, given all other attributes remain constant. Similarly, a parcel of land being further away from Vancouver would be cheaper by $10.60 per acre. Both prices suggest that location and transportation cost to the nearest town is on average approximately twice as important in affecting the land values that the more indirect effect of proximity to Vancouver. It is only reasonable that since the majority of the services and inputs are provided by nearby centres rather than by Vancouver, the attractiveness of being closer to the nearby centre would influence land values more.

The population of a nearby centre on average has a small negative effect on the land prices. A mean value of -$1.25 per acre was obtained. This is of some concern as population increases would tend to bid up the price of land in general. The mean value would therefore appear to have obtained the wrong sign. There is some evidence however that the distribution of this price is somewhat skewed as the minimum price obtained was -$20.49 while the maximum value was $3.75.

With the first stage results discussed, we can now proceed to evaluate the second stage results.

6.2 Second Stage Results

The system of bid functions for the four characteristics (i.e., month, distance from nearby centre, distance from Vancouver and the population of the nearest centre) were estimated with the symmetry restrictions and the normalizations imposed. These bid functions are provided by equation (25.2) of Chapter IV. For ease of reference, equation (25.2), or the bid price function for attribute j is:

$$\frac{\partial C}{\partial h_j} = \sum_i^I \sum_m^I a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{\frac{1}{2}} + 2y\sum_i^I c_{ij}w_i h_j + \tfrac{1}{2}\sum_i^I \sum_k^J b_{jk} w_i h_k^{\frac{1}{2}} h_j^{-\frac{1}{2}} + 2y\sum_i^I d_{ij} w_i h_j D \qquad (29)$$

All estimated coefficients, other than the a_{im}'s, are arranged in a matrix format in Table 3. For instance, the c_{ij} coefficient corresponding to the cross term between the distance to nearby centre and the price of feed in the distance from centre equation has the value of -.0210. Since the a_{im}'s

TABLE 3

BID FUNCTION ESTIMATES
(t-statistics in parenthesis)

Equ.	c_F	c_W	c_H	c_C	b_M	b_D	b_P	b_V	d_F	d_W	d_H	d_C
1	-.0022	.0001	-.00005	-.0005	0	-.0109	.0008	.0011	.0038	-.0001	.00004	.0005
M	(-.27)	(.43)	(-.11)	(-.27)		(12.18)	(3.22)	(2.65)	(.46)	(-.79)	(.08)	(.23)
2	-.0210	-.0003	-.0002	.0063	-	0	.0027	-.0037	.0144	.0005	.00032	-.0071
D	(-1.21)	(-.97)	(-.28)	(1.91)			(8.72)	(-3.85)	(.67)	(1.40)	(.35)	(-2.07)
3	.00006	-.000006	-.000003	.00003	-	-	0	-.0019	-.0001	.000002	.000009	-.00003
P	(.37)	(-3.30)	(-.51)	(1.41)				(-9.04)	(-.57)	(.87)	(1.21)	(-1.26)
4	-.0002	-.00002	-.000004	.0001	-	-	-	0	-.0002	.00002	.000003	-.0002
V	(-.17)	(2.13)	(-.22)	(2.01)					(-.15)	(2.24)	(.12)	(-2.29)

$a_{FW} = -6.5985$ (-3.61) $a_{FH} = .8529$ (4.01) $a_{FC} = -.2408$ (-1.49) $a_{WH} = .5285$ (3.20) $a_{WC} = 6.1244$ (3.46) $a_{HC} = -1.0690$ (-4.12)

where

Characteristics

M = month
D = distance to nearby centre
P = population
V = distance to Vancouver

Input Prices

F = feed
W = wage
H = hay
C = capital

are identical for each equation, they are listed under the other coefficients.

Once again, due to the particular functional form used, each of the coefficients in Table 3 does not have a straightforward interpretation. It is however, worth noting that all the own cross terms for the input prices, the a_{im} coefficients were significant at the 95 percent confidence level. This strongly implies that factor prices play an important role in the bid price determination process and supports our model as these prices are included as a consequence of the theoretical model.

Since one of the objectives of this thesis is to look at the underlying determinants of the bid functions for our four attributes, this relationship will be discussed first. The effects of a change in input price i on the bid price of characteristic j is provided by equation (25.5) of Chapter IV. These relationships were calculated at the sample mean for each of the 16 combinations and are presented in Table 4. As the bid functions include dummy variables to capture the possible shifts in the bid functions due to the land reserve program, two sets of calculations are provided. Column 1 of Table 3 would be the effects of input price changes on the various implicit prices before the program. Since each of the four implicit prices differ in magnitude, the second and fourth column of values are the absolute percentage changes in the corresponding implicit prices.

Restricting our attention to the pre-land figures (col. 1 of Table 4), the first interesting results are the signs of these effects.

The first effects considered are the ones associated with the month equation. It should be noted that the interpretation of changes in the bid price for month is not at all clear. This is due to the role

TABLE 4

Table of Changes in Bid Prices due to Changes in Input Prices

	Pre ALR Program	|% Δ|	After ALR Program	|% Δ|
∂M/∂F	-4.77	38.80	3.23	26.24
∂M/∂W	.29	2.32	-.05	.38
∂M/∂H	- .11	.86	-.03	.23
∂M/∂C	-1.21	9.79	-.23	1.84
∂D/∂F	9.86	51.21	-3.21	16.69
∂D/∂W	- .15	.80	.07	.36
∂D/∂H	- .11	.55	.05	.23
∂D/∂C	2.92	15.18	-.44*	2.26
∂P/∂F	.36	28.84	-.31	25.02
∂P/∂W	- .03	2.59	-.02	1.62
∂P/∂H	- .01	1.18	.04	3.41
∂P/∂C	.14	10.92	-.03	2.71
∂V/∂F	- .84	7.89	-1.52	14.33
∂V/∂W	- .07	.69	.01*	.12
∂V/∂H	- .01	.12	.01	.11
∂V/∂C	.64	6.08	- .16*	1.53*

* Significant at the 95% confidence level.

which time plays in the estimation. Its purpose is to represent the combined effects of factors which increase over time. This is analogous to the time trend variable commonly used in regression analysis. Since the four bid functions were jointly estimated, it is hoped that the inclusion of this equation would control for these time related elements.

The remaining three bid functions will basically capture the effects of urban pressures on agricultural production. Since the two distance bid functions capture the same factors, the effects of an increase in the same factor price should affect the two bid prices in the same direction. This was in fact the case for changes in the wage rate, hay price and the price of capital. The feed price however differs.

The next result addressed will be the effects of feed and hay price increases on the two distance bid prices. From the results, the effect of an increase in feed and hay prices on the implicit price of the distance from nearby centre attribute are $9.86 and -$.11 respectively. Similarly, the same price increases would affect the bid price for the distance to Vancouver attribute by -$.84 and -$.01 respectively. The relationship between feed and hay prices on the bid price of the two distances have interesting interpretations with regards to the feed and hay allocation choices of the dairy farmer. A dairy herd is typically fed alfalfa hay and a feed mix which is comprised of several selected grains. Protein supplements may be added but they are negligible compared to the other two components. Hay can be purchased but many dairy operations in B.C. grow much of that which they require on their farms. In contrast, feed mixes are generally purchased from feed outlets located in nearby centres. Since the feed supply companies in each region tend to be quite concentrated, they appear to compete on the characteristics of the feed than on the price. Feed prices would not therefore vary within different regions. Some dairy operations do grow and mix their own grains but such practices are not typical. Ideally, an optimal ration for a dairy herd would comprise both hay and feed. At the usual mean levels, a certain degree of substitution is possible with the optimal mix being determined by relative prices. An increase in the price of purchased feed would lead the farmer to purchase less feed and use more hay. Since hay is grown on the farm, each farm could reduce its cost by locating in areas further away from populated centres to take advantage of cheaper land to grow more hay. Since the bid price for distance is negative, the above discussion would suggest that the bid price would become less negative given an increase in the feed price. This was in fact obtained for the case of distance from nearby centre. This result, however was not obtained for the distance from Vancouver attribute price which would suggest that a wrong value was obtained for this value.

For the same feed price increases in the bid price for population equation, the results suggest that the bid price for population would increase by $.36 per acre. As suggested in the preceeding discussion, a feed price increase would lead dairy producers to grow more hay. An increase in hay production will generally require more labour thus it would be to the farm's advantage to be located closer to a populated centre to take advantage of a larger labour market. It is interesting to note that of all the absolute percentage changes of the bid prices, the effects due to feed increases is generally the largest for all four bid functions.

This result appears consistent as purchased feed constitutes a large component of the variable cost of a dairy operation.

For the case of an increase in hay prices, the results indicate that cost minimization behaviour would tend to favour purchases of plots closer to nearby centres as well as to Vancouver. The results also suggest that the same forces would favour a decrease in the population of a nearby centre. For the interpretation of these results, it may be instructive to distinguish between the consumption mix of the dairy herd. As previously stated, dairy herds in general consumes a feed mix and hay. Hay can be purchased or it can be grown on the farm. The feeding mix of the herd can therefore be said to be comprised of feed mixes, purchased hay and hay grown on the farm. Given an increase in the price of purchased hay, the farmer can substitute the ration by the other two components. Since feed prices do not in general vary for different regions, cost minimization behaviour would not result in any spatial preferences as far as feed consumption is concerned. Therefore, the last alternative would be to grow more hay on the own operation. As the population of nearby centres increase, the likelihood of urban sprawl pressures from nearby communities would increase. The effects of such activities would, among others, increase the surrounding land values. This would therefore affect the availability of farms to purchase lower price land to grow more hay. Using the same argument, it would appear that cost minimization behavour would favour lands which are located further away from populated centres for the above reasons. This would suggest that the two distance effects due to hay price increases would have the wrong sign.

An increase in the wage rate was found to have a decreasing effect on the bid price for population and an increasing one for the two distances. The distance result can be rationalized if one considers the opportunity cost of the farmer. As the wage rate of the farmer increases, this would imply that the opportunity cost of his time for off-farm activities would be higher. As the operator must make certain trips to either nearby centres or to Vancouver, cost minimization behaviour would favour the location of farms closer to these centres to minimize the travelling time. Given such a wage increase, it would therefore not be surprising to observe an increasing effect on the bid price for distance. Extending the above argument, an increase in the wage rate would also raise his value for recreational time since the income of the operator will also be increased. Assuming that a community which has a larger population will generally have better and more abundant recreational activities, there would be a certain desire for such additional activities if the worker's wage increases. However, since the results suggest that the relationship has an inverse effect on the desire for more people in a nearby centre, this would imply that a wrong sign was obtained for this value.

As the rental price of capital increases, the cost minimization model would suggest that land purchase decisions would favour purchases of land further away from both the populated nearby centre as well as from Vancouver. This price increase would also favour a larger population of the nearby centre. The capital term used in the model includes a measure for machinery and equipment. As the price of capita increases, forage activities would become more expensive since a certain amount of machinery is required for hay production. Given that the farmer would have a land purchasing decision to make at the time of an increase in the rental price of capital, cost minimization behaviour would lead the choice to lower price lands to compensate for the increase in rental price. As lands which are further away from populated centres are generally cheaper, the above result appears to be consistent. One explanation for the population result obtained would be based on the availability of capital. As a populated centre increases in population, the availability of capital in general would perhaps be relaxed since more lending agents would be in the market. So the desire to have access to a more competitive credit market would result in the farmers to favour a location which would be closer to a populated centre with more people.

Although the above results are not unanimously consistent with the expected industry behaviour, there does exist a large number of results which are consistent. As the previous result discussion can also be interepreted as being a rought form of model validation, there would appear to be some support for the proposed model. With the results evaluated, we can now proceed to evaluate the effects which the land reserve program had on the model in general and the bid functions in particular.

A likelihood ratio test was used to test for any effects the land reserve program had on the industry. A dummy variable was included in the model to control for such an effect. The restricted likelihood function value was obtained by estimating the system of equations without these variables and is equivalent to restricting all dummy variable coefficients to 0. As there are 4 binary variables in each equation, there will be 16 degrees of freedom. The unrestricted log likelihood function value was -2569.15 while for the restricted case, it is -2589.0. Minus twice the difference of the two values is 33.0. The Chi-square value at the 99.5% confidence level for 16 degrees of freedom is 34.27 and at the 99% level, it is 32.0. It appears that the program had a marginal effect on the industry since the null hypothesis is rejected at the 99.5% level and cannot be rejected at the 99% level. This should not really be that surprising if the parameter estimates are interpreted in the following context.

In the course of estimating the bid functions, we have also identified the cost function parameters since both can be expressed as functions of the same parameters. An alternative interpretation of the estimates is that we have also identified a cost function. In this interpretation, a test for the joint significance of the land reserve program is also a test for the significance of this program on the cost structure of the firm. (This interpretation has interesting implications and will be discussed in section 6.3). In terms of the total cost of a dairy operation, the rental price of land is quite small in relation to other factors such as feed cost and wage payments.

Although the joint significance is marginal, this does not rule out individual significance. By construction, the dummy variables were introduced such that each input price has a different dummy variable for each bid function. That is, there are 16 distinct binary variables. From equation (25.5), it can be seen that the test for the significance of d_{ij} would test for the program's effect of the i^{th} input price on the j^{th} bid function. Only three of the sixteen dummy variables were significant. The results that were affected were the changes in the two distance functions due to changes in the price of capital and the effect of a wage rate increase on the bid price for the distance from Vancouver.

Starting with the changes in the two bid prices for distance and how they are affected by increases in the price of capital, we can see that after the program, cost minimization behaviour would favour lands which are closer to the nearby centre as well as to Vancouver. Recall that before the program, the results suggest that increases in capital cost would favour locations further away to take advantage of lower price land for forage activities. Implicit in this result is the assumption that as a parcel of land is farther away from a centre, the price decreases. This would be primarily due to the urban pressures of the populated centres and is the basis for the concentric circle theory of land prices and development. However, if certain parcels are restricted for agricultural use by law, then the price of land closer to the centre may not be higher. So given an increase in the price of capital and the subsequent increase in the cost of forage activities, the farm may reduce its total cost by being closer to a populated centre.

The next bid price which was significantly influenced was the effect of wage increases on the bid price from Vancouver. From a desire to be closer to Vancouver before the program, the result suggests that after the program, the land purchase decision would favour parcels further away from Vancouver. This result appears to have the wrong sign as whether the program was in effect or not, farmers would cost minimize by locating closer to populated centres to reduce their opportunity cost for travelling for instance.

As we have estimated a system of bid or demand functions, it may be instructive to calculate the price flexibilities for each bid functions. The own price flexibilities were calculated for the four bid functions and are defined in the present study as:

$$f_{jj} \equiv \frac{\partial P_j}{\partial h_j} \cdot \frac{h_j}{P_j} \equiv \frac{\partial^2 C}{\partial h_j^2} \cdot \frac{h_j}{\partial C/\partial h_j} \tag{30}$$

where $\frac{\partial^2 C}{\partial h_j^2}$ is expression (25.4) and $\frac{\partial C}{\partial h_j}$ is (25.2). Price flexibility is a measure of the percentage effect on the price due to a one percent increase in the quantity. In the present study of price dependent bid functions, this measure is more appropriate than the conventional elasticity measure as f_{jj} can also be interpreted as being the responsiveness of changes in an endogenous variable due to a change in an exogenous variable. Although it is known that only under very restrictive conditions that the inverse of the price flexibility is equal to the demand elasticity (Houck 1965), a flexible price is generally consistent with an inelastic demand and an inflexible price is consistent with an elastic demand (Tomek and Robinson 1972). Own flexibilities are expected to be negative and is unaffected by negative implicit prices. The price flexibilities for the four attributes before and after the land reserve program is presented in Table 5. Only two of the dummy variables were significant after the land reserve program so only two after program flexibilities were calculated.

TABLE 5

Own Price Flexibilities

	Before Program	After Program
Month	1.70	-
Distance to Nearby Centre	- .31	-12.02
Population	5.50	-
Distance to Vancouver	.68	- .08

The results are somewhat discouraging as only one of the four flexibilities obtained the expected negative sign. For the case of the distance to nearby centre, the result suggests that the demand for this distance is relatively elastic as its value is less than one in absolute terms. That is, the market wide bid price of this attribute is insensitive to changes in quantity. It is interesting to note however that after the program, there is a significant change in the demand as it became inelastic. One explanation can perhaps be based on the possibility that the restrictive land measure may be relaxed. If urban land prices for a particular community reaches a high level, this would invariably result in pressure on the policy makers to take land out of the reserve. Since such an activity would undoubtedly result in huge profits for the land owner, this would provide a strong incentive for farmers to purchase land closer to nearby populated centres. This can perhaps also explain the significant change in the flexibility for the distance to Vancouver bid function.

6.3 An Alternative Interpretation of the Results

As previously mentioned, all cost function parameters are also contained within the system of bid functions. The cost function can therefore be recoverable from these bid function estimates and can be interpreted in some sense as being analogous to the conventional case of estimating a system of derived demand functions to obtain cost function parameters. This result suggests that just as the input choices of a firm can identify its cost conditions, input choices of the input attributes can also characterize such conditions. This interpretation of the parameters, if valid, has far reaching empirical implications. The most important of which is the possibility of identifying a cost function without quantity data. Characteristic composition of inputs, input prices and the output level are all that is required. This is an important concern as it is well-recognized among applied economists that although the modern flexible form duality approaches to production are appealing from a theoretical and empirical standpoint, this approach is extremely demanding in its data requirements. In the context of the cost functions, both price and quantity data are required to obtain cost function parameters either through derived demand functions (Lopez 1980), cost shares (Burgess 1979, Ray 1982) or by constructing the total cost and estimating the single equation cost function. Though price data are usually available, quantity data is generally much more difficult to obtain. If input attributes can be used instead of quantity data in cost function estimation, the proposed method would certainly be of interest to anyone under the undesirable situation of requiring cost function estimates without quantity data. The cost of such an approach would of course rest on the approximating ability of the hedonic function which links the input price and the attributes.

The idea of recovering the cost function from the system of bid functions is untuitively feasible. Just as input choices of the firm will reveal its cost minimizing behaviour, attribute choices can intuitively be used to identify the cost conditions since each input is a composite of these attributes. Whether we deal in the parent unit or in the attributes which comprise it, it would seem reasonable to suggest that looking at production from an attribute standpoint would provide us with similar information. The idea of looking at production from an attribute point of view is, of course, not new. It can however be seen as being an extension of the present empirical work. For instance, in agricultural production studies, it is well recognized that operator labour and hired labour are distinct inputs with different behaviours in the production process. There have been attempts to further disaggregate the labour component into educated and uneducated labour since educated labour is hypothesized to be more productive. This disaggregation of the inputs can be interpreted as being an attempt at dealing with the various attributes which comprise the inputs. It would appear that the need for disaggregating the inputs is a result of the recognition that each attribute has different properties and therefore would affect production in different ways. Disaggregating the inputs into subsets would address this issue, empirically speaking, but is only applicable when these subsets are freely traded and therefore resulting in observable explicit market prices. The difference of the proposed approach is that the land attributes are not freely traded explicitly.

The second implication which arises as a result of the first is that if the cost function can be recovered, then we have also identified the factor demand parameters. A simple way to measure the reliability of this result would be to derive the elasticities of these demand functions and see if they are consistent with the industry which is being modelled. Since quantity data is not available, exact elasticity values cannot be obtained. However, the signs of these elasticities can be inferred.

Applying Shephard's Lemma and recalling (25.3), we know that

$$\frac{\partial x_i}{\partial w_m} = \frac{\partial^2 C}{\partial w_m \partial w_i} = -\tfrac{1}{4}\hat{a}_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{-1\frac{1}{2}} + w_i w_m \sum_j^J h_j \qquad (25.3)$$

where x_i is the quantity demanded of input i. Since

$x_i, w_i, h_j > 0 \ \forall i,j$

$$\operatorname{sgn} \varepsilon_{im} = \operatorname{sgn} \frac{\partial x_i}{\partial w_m} = \operatorname{sgn} \frac{\partial^2 C}{\partial w_m \partial w_i} \qquad (31)$$

where ε_{im} is the cross elasticity between input i and m. It follows that:

$$\operatorname{sgn}[\varepsilon_{im}] = -\operatorname{sgn}[\tfrac{1}{4}a_{im}(\tfrac{1}{2}w_i^2 + \tfrac{1}{2}w_m^2)^{-1\frac{1}{2}} + w_i w_m \sum_j^J h_j]$$

$$\text{or} \quad \operatorname{sgn}[\varepsilon_{im}] = -\operatorname{sgn}[a_{im}] \qquad (32)$$

That is, the sign of the cross elasticities can be determined. These signs can therefore be used to determine whether any two inputs are substitutes or complements. From Table 3, the following relationships are suggested by the model:

TABLE 6

Table of Inferred Input Relationships

Inputs	-sgn (a_{im})	Input Relationships
Feed and Labour	>0	Substitute
Feed and Hay	<0	Complement
Feed and Capital	>0	Substitute
Labour and Hay	<0	Complement
Labour and Capital	<0	Complement
Hay and Capital	>0	Substitute

From the structure of the dairy industry, it is known that given a rise in the feed price, the dairy producer would use less feed and substitute the ration with more hay. Hay can either be purchased or grown on the farm. It is likely that the increase in feed price would result in the operation producing more hay and therefore would require more labour. Feed and labour in this case would therefore be substitutes. This result was obtained.

The feed and hay allocation choices have been discussed previously and have been labelled as being substitutes. However, in actuality, these two components are only substitutes within a specific region. The ration for dairy cattle must contain a minimum level of fibre for a proper diet. That is, the herd cannot exist in a healthy state if it was solely fed by hay. Since fibre can only be attained through the feed or grain component, after a critical level of feed content is reached, the hay and feed components can be interpreted as being complements.

Since the capital term includes machinery and equipment, as the price of capital increases, forage activities such as hay production would become relatively more expensive. This would lead the farmer to either purchase his hay or substitute his ration with feed. For the case of purchasing more feed, capital and feed can be seen as substitutes.

Labour and hay were estimated to be complements. This result appears to have the wrong sign as labour and hay should be substitutes. As hay prices increase, the farmer would attempt to obtain more hay from his farm so as to minimize the purchase hay. Since more forage activities are required, this would lead the operator to require more labour. Labour and hay would therefore be substitutes.

The labour wage rate used in the present study is the farm wage rate with board. The representative farmer can therefore be classified as skilled labour. It is generally accepted that skilled labour are complements with capital as skilled labour are required to operate the machinery. Complementarity was obtained in our result.

Hay and capital can be seen as substitutes since as hay prices increase, the operation would produce more of its own hay which would require more extensive use of the capital in the farm. This relationship was reflected in our results.

Of the six relationships arrived at, only one has a suspicious sign. It would appear that this approach of looking at the relationships among inputs have some support in that realistic results were obtained in five of the six cases.

CHAPTER VII

CONCLUSION

This thesis, through the integration of hedonic and production theory, provided a method of deriving a system of bid functions for land attributes for the B.C. dairy industry. The system of bid functions were derived from cost minimizing behaviour of the industry. Estimates of the system were obtained and evaluated with respect to the relationship between bid prices of the various attributes and how they are affected by non-land factor price changes.

The results suggest that feed price changes on average, played a dominant role in the bid price determination for land attributes. Also, the feed and hay allocation choices appear to be very much related to the land attribute choices of the farm. It was also shown that the agricultural land reserve program had only a marginally significant effect on the bid prices.

Perhaps the most interesting results arising from this study are the various applied implications of the proposed model. As it turns out, in the context of production, endogenous as well as exogenous implicit prices are important considerations in the systematic derivation of bid functions from the cost function. It was suggested that linear homogeneity of the hedonic function is a necessary condition for exogenous implicit prices. This result can therefore either be the basis of a statistical test to determine whether certain implicit prices are exogenous or endogenous or it can be used to impose economic structure into the specification of the hedonic function. This is an important result since in the existing literature, no economic structure is available to determine the functional form of the hedonic function. Researchers have traditionally used statistical criterias to determine the appropriate specification (Halvorsen). Imposition of a priori structure derived from theory would undoubtly strengthen the model.

Another result which has far reaching implications is the possibility of identifying cost function parameters from the system of bid functions. If such a procedure is valid, then the hedonics approach in production can be seen as another method of obtaining production parameters. Also, identification of cost function parameters would necessary also identify the factor demand function parameters. Since this would suggest that cost function parameters can be estimated without quantity data, the empirical implications of this result would appear to be of some importance. Although this result is suggested, it is suspected that more theoretical developments are required before such a procedure can be operationalized.

Although this thesis did provide several interesting results and that it met the objectives originally set out, it is not without its shortcomings. The most important and potentially damaging of which are the implicit and unknown assumptions placed on the production function when both the cost and hedonic functions are prespecified. It is not clear that in such a circumstance, the usual duality results with respect to the underlying production function still apply. The answer can be obtained by deriving a set of local duality results as in Blackorby and Diewert (1979) for the case of nonlinear budget constraints. It is suspected that such an exercise would be a thesis in itself. Acknowledging that this is indeed a serious concern, this problem cannot be feasibly addressed in the present study.

Another downfall is the relative complexity of the functional form used. This results in several problems with the dominant one being that the comparative static expressions are extremely complicated. Their functional forms does not allow for an easy calculation for the statistical properties of these results. It was therefore not possible to statistically test for the significance of some of the effects. This is an important concern as the effects can, in some cases, be neutral or is not significantly different from zero.

Despite the previous mentioned shortcomings, the approach provided does address an important area of economics, the characteristic choices of factors of production. Through the proposed model, it can be seen that such an analysis has the potential of supplying more detail with respect to the behaviour of the firm.

REFERENCES

Alonso, W., "The Demographic Factor in Housing for the Balance of this Century." Paper prepared for the symposium on 'North American Housing into the 21st Century', July 1981, UBC.

Archibald, C., and Rosenbluth, G., "Production Theory in Terms of Characteristics: Some Preliminary Considerations," Discussion Paper No. 78-19, May 1978, Department of Economics, UBC.

Barnard, C., and Butcher, W., "Landowner Characteristics as Determinant of Developer Locational Decisions". Paper presented at the AAEA meetings in Clemson, South Carolina, July 1981.

Becker, G., "A Theory of the Allocation of Time," Economic Journal, 75(1965) 493-519.

Berndt, E., "Quality Adjustment in Empirical Demand Analysis", paper prepared for Statistics Canada Conference on Price Measurements, November 1982, Ottawa.

Binswanger, H., "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution." American Journal of Agricultural Economics, 56(1974), 377-386.

Blackorby, C., and Diewert, W. E., "Expenditure Functions, Local Duality, and Second Order Approximations." Econometrica, 47(1979), 579-701.

Brereton, S., "Refrigerators: A Hedonic Regression Analysis of Energy Costs and Conservation Possibilities for Consumer Durables." Unpublished extended M.Sc. Essay, July 1979, Department of Economics, UBC.

Brown, J. and Rosen, H., "On the Estimation of Structural Hedonic Price Models." Research Memo No. 284, June 1981, Econometric Research Program, Princeton University.

Burgess, D., "Duality Theory and Pitfalls in the Specification of Technologies." Journal of Econometrics, 3(1975), 105-121.

Chavas, J. and Shumway, R., "A Pooled Time-Series Cross-Section Analysis of Land Prices." Texas Ag. Experiment Station, Article No. 16084, 1981, Texas A & M University.

Christensen, L., Cummings, D., and Schoech, P., "Econometric Estimation of Scale Economies in Telecommunications." Social Systems Research Institute Workshop Paper No. 8124, September 1981, University of Wisconsin.

Christensen, L., and Greene, W., "Economies of Scale in U.S. Electric Power Generation," Journal of Political Economy, 84(1976) 655-676.

Christensen, L, Jorgenson, D., and Lau, L., "Transcendental Logarithmic Production Frontier," Review of Economics and Statistics, 55(1972) 28-45.

Denny, M., "The Relationship Between Functional Forms for the Production System," Canadian Journal of Economics, 7(1974) 12-20.

Dhrymes, P., "Price and Quality Changes in Consumer Capital Goods: An Empirical Study," Price Indexes and Quality Change, ed. Z. Griliches, Harvard University Press, (1971) 88-149.

Diewert, W. E., "Functional Forms for Profit and Transformation Functions," Journal of Economic Theory, 6(1973) 284-316.

Diewert, W., "Applications of Duality Theory," Frontiers of Quantitative Economics, vol. 2, ed. M. D. Intriligator and D. A. Kendrick, Amsterdam: North-Holland Publishing Co. 1974.

Edlefsen, L., "The Comparative Statics of Hedonic Price Functions and Other Nonlinear Constraints," Econometrica, 49(1981) 1501-1520.

Epple, D., "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products," mimeo, Carnegie-Mellon University, August 1980.

Epstein, L., "Generalized Duality and Integrability," Econometrica, 49(1981) 655-678.

Goldberger, A., "Linear Regression in Truncated Samples," manuscript, Social Systems Research Institute, University of Wisconsin, 1973.

Goldman, F., and Grossman, M., "The Demand for Pediatric Care: An Hedonic Approach," Journal of Political Economy, 86(1978) 259-280.

Griliches, Z., "Hedonic Price Indexes for Automobiles," Price Indexes and Quality Change, ed. Z. Griliches, Harvard University Press, Cambridge, 1971.

Halvorsen, R., "Choice of Functional Form for Hedonic Price Equations," Journal of Urban Economics, 10(1981) 37-49.

Harrison, D., and Rubinfeld, D., "Hedonic Housing Prices and the Demand for Clean Air," Journal of Environmental Economics and Management, 5(1978) 81-102.

Hausman, J., and Wise, D., "Social Experimentation, Truncated Distributions and Efficient Estimation," Econometrica, 45(1977)919-938.

Houck, J., "The Relationship of Direct Price Flexibilities to Direct Price Elasticities," Journal of Farm Economics, 47(1965) 789-792.

Hurwicz, L., and Uzawa, H., "On the Integrability of Demand Functions," Preference, Utilities and Demand, ed. J. Chipman, New York: Harcourt, Bruce and Co., 1971.

Intriligator, M., Mathematical Optimization and Economic Theory, Prentice-Hall Inc., Inglewood Cliffs, N.J., 1971.

Johnston, J., Econometric Methods, McGraw-Hill Book Company, New York: N.Y., 1972.

Kain, J., and Quigley, J., "Measuring the Value of Housing Quality," Journal of the American Statistical Association, 65(1970) 532-548.

King, T., "The Demand for Housing: A Lancastrian Approach," Southern Economic Journal, 43(1976) 1077-1087.

Kmenta, J., and Gilbert, R., "Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regressions," Journal of the American Statistical Association, 63(1968) 1180-1200.

Lancaster, K., "A New Approach to Consumer Theory," Journal of Political Economy, 74(1966) 132-157.

Linneman, P., "An Empirical Methodology for Analyzing the Properties of Public Goods," Economic Inquiry, Oct., (1980) 600-616.

Lopez, R., "The Structure of Production and the Derived Demand for Inputs in Canadian Agriculture," American Journal of Agricultural Economics, 62 (1980) 38-45.

Lucas, R., "Hedonic Price Functions," Economic Inquiry, 13(1975) 157-178.

Lucas, R., "Hedonic Wage Equations and Psychic Wages," American Economic Review, 67(1977) 549-558.

Melichar, E., "Capital Gains Versus Current Income in the Farming Sector," American Journal of Agricultural Economics, Dec. (1979) 1085-1092.

Muth, R., "Household Production and Consumer Demand Functions," Econometrica, 34(1966) 699-708.

Parks, R., "Price Responsiveness of Factor Utilization in Swedish Manufacturing, 1870-1950," Review of Economics and Statistics, 53(1971) 129-139.

Quan, D., and Kerr, W., "Truncated Estimates for Incomplete Technical Change in the Canadian Cattle Industry," forthcoming in the American Journal of Agricultural Economics, Aug., 1983.

Quigley, J., "Nonlinear Budget Constraints and Consumer Demand: An Application to Public Programs for Residential Housing," Working Paper No. 80-17, September 1980, Centre for Real Estate and Urban Economics, University of California, Berkeley.

Ray, S., "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77," American Journal of Agricultural Economics, Aug. (1982) 490-498.

Rosen, S., "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," Journal of Political Economy, 82(1974) 34-55.

Shephard, R., Theory of Cost and Production Functions. Princeton University Press, Princeton, New Jersey, 1970.

Spady, R., and Friedlaender, A., "Econometric Estimation of Cost Functions in the Transportation Industries," Report No. 76-13, Sept. 1976, Centre for Transportation Studies, Massachusetts Institute of Technology.

Theil, H., Principles of Econometrics, John Wiley and Sons, New York, N.Y., 1971.

Tomek, W. and Robinson, K., Agricultural Product Prices. Cornell University Press, London, 1977.

Varian, H., Microeconomic Analysis. Norton and Co., New York, N.Y., 1978.

Wills, H., "Estimation of a Vintage Capital Model for Electricity Generating", Review of Economic Studies, (1978) 495-510.

Witte, A., Sumka, H., and Erekson, H., "An Estimate of a Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit Markets," Econometrica, 47(1979) 1151-1173.

Zarembka, P., "Transformation of Variables in Econometrics," Frontiers in Econometrics, New York; Academic Press, 1974.

Zellner, A., "An Efficient Method of Estimating Seemingly Unrelated Regression and Tests for Aggregation Bias," Journal of the American Statistical Association, 57(1962) 348-368.

Zellner, A., and Huang, D., "Further Properties of Efficient Estimators for Seemingly Unrelated Regression Equations," International Economic Review, 3(1962) 300-313.

PUBLICATIONS

(1) Quan, D. and Kerr, W.,"Truncated Estimates for Incomplete Technical Change in the Canadian Cattle Industry", American Journal of Agricultural Economics, Aug. 1983.

(2) Quan, D. and Kerr, W., "Ongoing Technological Change in the Canadian Beef Cattle Industry - An Example of Estimation with Truncated Samples," discussion paper #82-01, Dept. of Agricultural Economics, University of British Columbia, 1982.

(3) Quan, D. and Casey, D.,"The Effect of Model Misspecification on Forecasting Error for Box-Jenkins Time Series Models," discussion paper #82-02, Dept. of Agricultural Economics, University of British Columbia. 1982.