AN ABSTRACT OF THE THESIS OF

Chrispen Sukume for the degree of Doctor of Philosophy in Agricultural and Resource Economics presented on November 20, 1992.

Title: Effects of U.S. Commodity Programs on Farm Growth

Redacted for Privacy

Abstract approved: ______________________________

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The U.S. farm sector has undergone dramatic structural change during the past fifty years, a chief result being that the number of large farms has increased relative to the number of small farms. Numerous agricultural policies have been instituted, with the partial objective of preserving the family farm. At the same time, a number of studies have attempted to ascertain the contribution of various forces, including farm programs, toward the observed changes in average farm size. These studies have tended to concentrate on aggregate effects, ignoring farm-level and dynamic effects of program and nonprogram factors on farm growth.

The present study overcomes such limitations by utilizing a farm-level dynamic growth model which links consumption, production, and investment decisions. Steady-state comparative static and local comparative dynamic analysis of the dynamic model solutions indicate qualitative effects of program and nonprogram factors on farm growth. Simulation of quantitative effects are

conducted on econometric estimates of the dynamic model solutions, using Kansas wheat farm data.

Empirical results show that set-aside-percentage-type instruments (required and voluntary set-aside percentages) induce longrun net equity increases in small farms and longrun net equity decreases in large farms. In both size classes, set-aside instruments increase longrun land holdings, the increases being greater in larger than in smaller farms. After considering effects on rented land, the effect of set-aside-type instruments on overall scale of operation is negligible.

Payment-rate-type instruments (per-acre deficiency, voluntary and paid diversion payment rates) increase longrun net equity and consumption in both small and large farms. They lead to longrun land ownership increases in small farms and decreases in large farms. However, they lead also to increases in rented land, the increase being greater in larger than in smaller farms. Net effect on scale of operation is nonsignificant.

Finally, nonprogram factors affect growth also. Technical change increases net equity and landholding in large farms more than in small farms. In both large and small farms, increases in prices of land's substitutes, lead to net equity increases, whereas increases in prices of complements reduce net equity. In the longrun, output price increases encourage consumption and reduce net equity.

Effects of U.S. Commodity Programs on Farm Growth

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed November 20, 1992

Commencement June 1993

APPROVED:

Redacted for Privacy

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Date thesis is presented November 20, 1992

Typed by researcher for Chrispen Sukume

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Effects of U.S Commodity Programs on Farm Growth

CHAPTER I

INTRODUCTION

In the past three decades the U.S. agricultural sector has experienced dramatic structural changes (Table 1.1). The number of farms currently operating is less than half of that in 1950. During this period the number of part-time farmers has more than doubled. A close look at the size distribution reveals that the proportions of large and small farms have grown relative to medium-sized farms. Accompanying this structural shift is a drop in the percentage of the U,S. population residing in rural areas, from 15 percent in 1950 to only two percent in 1987.

The question of what forces have led to these developments have long been on agricultural economists' research agenda. Historically, the concern that has motivated these studies and much of the political argument on the subject stems from a desire to preserve the "family farm" (Talmadge, 1980). This is a rather vague term which has been defined differently by different observers, as discussed by Sumner (1985). Generally, the term has come to convey the sense that a family farm is a medium-sized farm "...where the family owns at least some portion of the land, supplies a majority of the labor, and controls the production and marketing decisions" (Smith, Richard, and Knutson, 1985, p. 365). Buettel (1983) suggests the concern for family farm agriculture historically arose due to the view that the family farm is "...a democratic

Table 1.1. Farm Structure, 1900-1987.

Year	# of Farms (000)	Ave. Farm Size in acres	Small Size Farms 1-99 acres (%)	Medium Size Farms 100-499 acres (%)	Large Size Farms >500 acres (%)	Farm Population (%)
1900	5739	147	57.48	39.92	2.61	n.a.
1910	6366	139	58.04	39.21	2.76	n.a.
1920	6453	149	58.54	38.09	3.37	30.1
1930	6295	157	59.36	36.81	3.82	24.9
1940	6102	175	58.71	36.96	4.33	23.2
1950	5388	216	55.98	38.38	5.63	15.3
1959	3710	303	46.23	44.70	9.07	9.4
1969	2730	389	40.13	46.45	13.43	5.1
1978	2257	449	39.80	43.62	16.58	3.7
1982	2240	440	43.76	39.91	16.33	3.0
1987	2088	462	43.42	38.91	17.67	2.0

Sources: U.S. Census of Agriculture, for the first 5 columns. Statistical Abstract of the United States, for farm population.

alternative to the frequently grossly unequal land holding systems of Western Europe...." (p. 88).

Sumner argues that the family farm motive is not, and should not, be the objective in looking at policy effects on farm structure. He argues that policies designed for purposes other than effecting a particular structure may nonetheless have unintended effects on structure and which should be revealed to help inform policy making. Another usefulness of analyzing policy effects, he points out, is in forecasting changes likely in the farm economy, and other related sociological phenomena such as rural to urban migration.

The predominant explanation for the shift toward large farm sizes in the agricultural sector has been the "treadmill" process (Cochrane (1979)). Cochrane's argument is that the move toward large-scale farming is largely due to technological advancements which lower unit production costs. Early adopters of new technologies reap temporary gains. In the long term, these temporary gains became capitalized into real estate values. This has several effects. The initial windfall gains by early adopters enable them to invest more in land before these gains are bid into higher land values. Secondly, the rise in fixed factor costs raises production costs to late adopters. Thirdly, the increase in production brought about by technological advances reduce output prices, further squeezing the late adopting, and predominantly smaller farmers, with lower credit worthiness. Government subsidy programs in this theory further accelerate the process since, while small farmers use subsidies to cover their losses from the "treadmill," large and profitable farmers can use the program benefits to invest in still more land, such that in the long-run, program benefits themselves become capitalized into land values.

More recent studies have tried to put more structure to the basic Cochrane model. Studies by Rogers (1991) and Leathers (1992) adopt the model by Lucas (1978), which uses the theoretical construct of "managerial talent" in place of the "late adopter"-"early adopter" characterization of Cochrane. Other studies employ a general equilibrium formulation as in Rausser, Just, and Zilberman (1982), which includes a more detailed structure of current farm programs. The many results of these formulations confirm the asset value augmenting effect of farm programs.

The asset enhancing emphasis taken in the prevalent studies on program effects requires a general equilibrium modelling approach, which entails aggregating over all farm units. However, as Sumner (1985) and Gardner (1987) argue, size distribution emanates from, among other factors, differences in financial constraints, technology, and incentives; and farm programs directly affect farm size distribution through their effects on these factors. Aggregation forces the analyst to assume uniformity in characteristics among farmers, preventing the research from deriving the direct effects of programs on farm growth. Another characteristic of the earlier studies is that they look at changes in long-run equilibrium values and ignore the dynamic adjustment process in the interim. Finally, data are usually not available to empirically test these models.

The purpose of this study is to offer an alternative, albeit limited, view to the above discourse which emphasizes the dynamic farm level growth effects of farm programs and market conditions on different farm size classes. By concentrating at the farm level, the study brings into the analysis hitherto overlooked factors such as land tenure, off-farm income, financial conditions, technology, and preferences. What is lost with this approach is the ability to infer whether or not farm programs lead to capitalization of program benefits into land prices. It is hoped that the ability to infer direct program effects outweighs this disadvantage. The study emphasizes farm contraction and expansion effects rather than farm numbers themselves. However as Day and Sparling (1977) have noted, "(e)conomic development in agriculture (in the absence of a geographic frontier) usually involves the growth of some farm firms and the decline or abandonment of others" (p. 100). Revealing these direct growth effects should enable one to infer effects on farm size distribution.

More specifically this study aims to answer the following research questions:

(1) What are the qualitative farm-level growth effects of government programs and market variables?

(2) How have farm programs and market variables affected the farm-level growth of predominantly wheat growing Kansas farms in different size classes?

To achieve objective (1), the study develops a growth theoretic model based on models by Chambers and Lopez (1985), Chambers (1984), and Chambers and Phipps (1987), explicitly incorporating the major grain farm program instruments, acreage diversion, target price, voluntary diversion, loan rate, and conservation requirement. Qualitative properties are deduced by performing steady-state comparative statics and local comparative dynamics using Caputo's methodology (1989).

The study uses net equity, the value of assets less accumulated debt, as the investment stock instead of land because net equity is neutral to land quality. The problem with using land quantity is that it varies in quality from parcel to parcel. Another advantage with using net equity is that it reflects the financial health of the farm business.

To achieve objective (2) the study estimates, using individual farm data on production costs, family on-farm and off-farm income, land use and production, the parameterized optimality conditions of the growth theoretic model for different size classes. Individual farm data comes from the Kansas Farm Management data bank, managed by the Kansas State Extension Service. Participation in the farm management association is voluntary, which means the data may not be truly representative of Kansas farmers. The estimates based on this data are then used to simulate long-run and local comparative dynamic effects on growth of farm programs and market variables.

In the next section, a summary review of past studies of the determinants of growth and farm distribution changes is presented. Chapter II outlines the theoretical farm growth model and discusses the qualitative effects on growth of farm program instruments and other market factors. Chapter III adapts this model for empirical estimation. The discussion continues in Chapter IV with a description of estimation techniques and hypothesis tests. A more detailed review of data sources and manipulations is provided in Chapter V. Chapters VI and VII, respectively, discuss econometric results and empirical growth effects. Finally, Chapter VIII summarizes and concludes the main study results.

1.1 Past Studies

During the 1960s and 1970s, the predominant approach to discussing determinants of structural change was the Marshall-Viner theory of supply (Quance and Tweeten, 1972; Madden and Partenheimer, 1973; and Suits, 1986). This is the approach which spawned Cochrane's "treadmill" theory.

The Marshall-Viner approach assumes that farm firms have identical U-shaped long-run average cost curves and, hence, have a single optimum scale of operation. This implies that farms operating at less than the optimal scale are operating under financial stress. The trend toward fewer and larger farms in this framework has been attributed to technological change through the "treadmill" process of Cochrane. Technological advances lower the minimum cost of production and increase the optimum scale. Farms which adjust quickly and take advantage of these advances, usually large farms with better credit worth, reap early windfall gains which they can use to increase their operation. With time, however, the gains are capitalized into land values, making it difficult for smaller late adopting farms to expand. The high land values might actually encourage these farmers to sell land.

In this approach farm programs would lead to an increase in average farm size (Quance and Tweeten, 1972). Farm price support program gains would help relieve financial stress of smaller farmers who operate at suboptimal scale. Large-scale farms, because they are in better financial condition, can use the extra income from price supports to grow. In the long-run all the gains are capitalized in rents raising the opportunity costs of land for smaller farmers. This encourages them to sell some land or go out of farming. Thus, farm programs lead to a decrease in farm numbers and the average farm size.

The general approach presented above has some limitations. The first is that the model ignores dynamic adjustments caused by changes in program and exogenous factors. Secondly, the structure of the model is not amenable to discussing other forms of programs such as acreage reduction and thirdly, because of its emphasis on the aggregate effects, one cannot recover the direct effects of programs on farm growth. Gardner (1978) also pointed out, that arguments used to capture growth effects in these studies might be faulty. For instance, per unit gain from programs is the same for large and small farmers. The farmer who gains the most from programs, Gardner argues, is one "to whom a given dollar increase in net returns per bushel is worth the most" (p. 837), which is the small, higher cost producer and not the large farmer. Furthermore, empirical evidence reviewed by Gardner and Pope (1978) does not support the view of a unique optimal farm size.

More recent studies have tended to move away from the concept of one unique optimal farm size. Sumner's view is that size distribution is the result of optimizations by individual farmers who differ in their endowments of physical, financial, and human capital, and have different technologies and preferences. Farm programs affect size distribution through their effects on these factors.

Sumner's view is operationalized in one aspect by Lucas model of distribution of firm size (1978). Studies that have adopted Lucas' model include recent ones by Leathers (1992) and by Rogers (1991). In the Lucas' approach, following Leathers (1992), a farmer or potential farmer is assumed to possess an endowment of land, L, and an ability level, k, which is distributed as F(k) throughout the population. The individual can rent in or out R amount of land at a rental rate, r. Profit maximization for an individual of ability level k becomes:

$$Max_{YL} \; Z = P \cdot Y - C(Y, L-R) - R \cdot r + g$$

subject to:

$$L \geq R \qquad (y, L-R) \in T(k)$$

where y is output; Z is profit; T(k) is the feasible production set for an individual of ability k; C(•) is a short-run cost function, and g is the sum of net farm program benefits. The constraints say that the farmer cannot rent out more land than he possesses and production must be feasible.

The above optimization results in an indirect profit function Z(P, r, k, g), which by Hotelling's lemma yields planted acreage of:

$$L^* - R^* = -Z_r (P, r, k, g).$$

If $-Z_r(\bullet)$ is a monotonically increasing function of k, we can recover the potential distribution of land planted, hence farm size distrbution, in the population, H(k, P, r, g), through the "change-in-variable" mathematical statistical technique.

Factors in the non-farm economic environment affect this distribution through opportunity wages. An individual goes into farming if profits, Z, are greater than opportunity wage. The individual's opportunity wage depends on his human capital and how the non-farm sectors are faring. This line of argument explains the concentration in the U.S. farms as partly due to relatively higher incomes in the nonfarm sectors raising the opportunity wages of low ability individuals above possible farm profits. Effects of government programs are investigated through their effects on H(•) and the real estate market. The major conclusion from this approach is that farm program effects get capitalized into land values.

The Lucas approach, like the Marshall-Viner approach, is based on comparative static analysis and does not address dynamic adjustment effects and cannot facilitate analysis of changing farm program instruments. Furthermore, models employing the Lucas approach are difficult to test empirically because some of the variables, such as ability, are difficult to measure and data for a complete equilibrium study generally not available.

A model which is flexible enough to include most government programs, while at the same time considering financial constraints on farms, is one by Rausser, Just, and Zilberman (1984). Additional features of this model are that it takes into account heterogeneous land qualities, heterogeneous production technologies, and financial constraints. Theoretical qualitative results of the model indicate that land controls tend to benefit landowners rather than operators. Also farm programs raise land prices relative to rental prices and encourage adoption of technologies. Empirical evidence to test these propositions is based on regional comparisons of land, technology and financial conditions, and farm program participation. They find that program participation tends to be higher in regions with high production costs, less efficient technology and marginal land.

The Rausser-Just-Zilberman model, however, does not consider dynamic adjustment effects. The empirical evidence to support their propositions is only suggestive.

Another line of inquiry into effects of policy on farm structure has been simulation studies. These studies look at changing probability of farm survival under alternative policy and market conditions. Two such studies that look at farm program effects on farm survival and growth are those by Leatham, Perry, Rister, and Richardson (1986) and by Smith, Richardson, and Knutson (1985). The later deals primarily with effects of farm programs. The general approach is to survey different size classes of farms and to identify within each class, a farm possessing approximately the mean characteristics of that class with respect to features like production cost, acreage controlled, marketing and organizational practices, and participation in government programs. Based on information from these typical farms, simulations of probability of survival, success, and growth are performed under alternative farm policy variable scenarios. Using this approach, Smith, Richardson, and Knutson (1985) analyzed effects of all the major cotton programs on Texas Highlands cotton farms, and concluded that farm programs tend to help medium-sized farms and have little effect on small and large farms.

The simulation approach, however, is prescriptive rather than descriptive, and thus cannot answer the question of what effect farm programs have had on farm growth. Because it looks at farm level effects, the simulation approach cannot infer the indirect effect of programs on farm size through land prices. However, the simulation approach has the advantage of being able to include many program crops in the analysis which is difficult, if not impossible, with the other approaches.

The approach taken in the present study emphasizes direct farm level growth effects as in Smith, Richardson, and Knutson (1985), but with an aim of to describing and hypothesis testing. The present study also analyzes the dynamics of the policy effects . The theoretical framework used here builds on Chambers and Lopez's (1985) model which they use to analyze tax policy effects on family farms. Their model has some attractive features. It assumes that farmers make consumption and production decisions simultaneously; which is in accord with previous analyses which indicated that "... the farmers' production decisions are not separable from their consumption/leisure choices" (Evans, 1976). Bollman (1979) proves that consumption and production decisions are separate only when farmers have no nonfarm income. Another attractive feature of Chambers and Lopez's model is that it collapses debt and land stocks into one variable, net equity, which reduces the dimensionality of the dynamic model, making discussion of qualitative properties easier to undertake.

CHAPTER II

THE MODEL

This chapter develops a theoratical model of farm growth in the presence of farm programs and discusses its qualitative properties.

2.1 Net Equity Accumulation Model

In this section, I develop a model of farm household time and income allocation based on utility maximization. Time can be used working off-farm to earn wages, working on-farm, and in leisure activities. Farmers are assumed to maximize utility (U) from consumption of a composite good, valued at C, and leisure time, l. Leisure is the difference between total time available (H) and time used for on-farm work (L_1) and off-farm work (L_2). Mathematically, the above problem can be specified as:

$$\max_{C,L_1,L_2} \int_0^{\infty} U[C(t),H-L_1(t)-L_2(t)]\ e^{\delta t}\ dt \tag{2.1}$$

subject to:

$$E' = \frac{\partial E}{\partial t} = I(P,W,\phi,L_1,E) + W_oL_2(t) - C(t) + Y_1$$

$$E(0) = E_0$$

where I(.) is income from farming, W_0 is the off-farm wage rate, δ is the discount rate and Y_1 is a variable that captures other non farm operation generated income the farmer gets such as rent from non farm property and gifts. Farm income, I(.) is expressed as a function of output price (P), input prices (W), L_1, net equity (E), and a vector of other exogenous factors (ϕ), including farm program variables and technological shifters which are dicussed in section 2.5.

The utility function curvature properties presumed by Chambers and Lopez (1985) are maintained in this study. In particular,

$$U_c > 0 \,;\, U_l > 0 \,;\, U_{cc} < 0 \,;\, U_{ll} < 0 \,;\, U_{cl} \geq 0$$

and $U_{cc}U_{ll} - U_{cl} > 0$. That is, I assume a non-decreasing strictly concave utility function. These are somewhat stronger assumptions than theory dictates (see Varian, p. 96) but most growth studies have used the Cobb-Douglas specification, which imposes even stronger assumptions.

The infinite horizon specification used here is defended on the grounds that, in addition to his own lifetime consumption, a farmer also derives utility from the consumption of his descendants (Love and Karp (1988); Chambers and

Lopez (1987)). Chambers and Lopez defend their deterministic model by arguing that optimal planning rules derived from such an optimization are not meant to be set and followed in perpertuity, but are constantly updated as new information becomes available.

The state constraint is a dynamic version of the income-expenditure constraint. To see this, move C to the left hand side. This equates current expenditure, consisting of change in investment and consumption, with current income from on- and off-farm work, and other non-farm income.

The inclusion of net equity as a variable affecting income is a way to reflect farm failure risk. A low net equity position increases the risk of loan defaults. Farmers can respond to low net equity positions in two different ways. They can sell some land to pay off excess debt or they can refinance loans at higher interest rates which banks require for high-risk loans. Firm failure risk has been modelled by Love and Karp (1988), Kim (1991), and Salchenberger and Stefani (1990) by specifying a probability of firm failure function, F, dependent on net equity and modifying the owner's dynamic problem to be

$$\max_{C,L_1,L_2} \int_0^\infty (1-F)U(C,l)e^{-\delta t}\, dt \qquad (2.2)$$

subject to:

$$\frac{\partial A}{\partial t} = I(\phi,W,L_1,A) + w_0L_2 - C + Y_1$$

$$\frac{\partial D}{\partial t} = \delta D + P_L\frac{\partial A}{\partial t} - RP$$

$$\frac{\partial F}{\partial t} = (1-F)\theta$$

where D is accumulated debt, P_L is land purchase price, A is land area, RP is debt repayment, and θ is the probability of farm failure conditional on net equity. This is a far more complicated problem to analyze than that specified in (2.1), which has two fewer states than (2.2).

I adopt here the approach taken by Chambers (1984), and by Chambers and Lopez(1987), in which the risk effect of the net equity position is reflected through bank interest charges. An added advantage of this approach is that it reduces the debt and land state relations into one net equity state.

Current farm income is defined as

$$I = \max_A[\pi(P,W,\phi,A,L_1) - r(E)(AP_L - E)] \tag{2.3}$$

where $\pi(.)$ is a restricted profit function, conditional on A and L_1, and r(E) is the effective loan interest rate. The function r(E) is presumed to be a decreasing strictly convex function of E. A more detailed look at $\pi()$ is defered to section (2.5).

Chambers (1985, p.393) specifies r(E) as

$$r = r0 + g(E) \tag{2.4}$$

where r0 is the risk-free interest rate and g(E) is the risk "premium" banks charge for percieved risk of failure. The function g(E) is a decreasing strictly convex function of net equity to reflect the lower risk associated with a high net equity position.

Applying the Envelope Theorem to I(.) yields

$$I_E = -r_E(A^*P_L - E) + r \quad > 0 \tag{2.5}$$

since r(E) is a decreasing function of E. The economic interpretation of (2.5) is that an increase in net equity increases farm income in two ways. The first right hand expression represents savings in debt servicing which result from a lowering in the effective interest rate. The second expression gives the direct effect unit value of net equity, which is the interest rate. Further differentiation gives

$$I_{EE} = -r_{EE}(A^*P_L - E) + 2\, r_E - (r_E)^2 A^*_r \, P_L \tag{2.6}$$

which is assumed negative.

The current value Hamiltonian to problem (2.1) is (ignoring time subscripts)

$$V = U(C,l) + \eta(I + w_0 L_2 - C + Y_1) \qquad (2.7)$$

where $^{\text{n}}$ is the current value costate variable or shadow price of net equity. Applying the maximum principle to (2.7) results in the following optimality conditions:

$$\begin{aligned}
U_C - \eta &= 0 && \text{(i)} \\
-U_l + \eta I_L &= 0 && \text{(ii)} \\
-U_l + \eta w_0 &= 0 && \text{(iii)} \\
I + w_0 L_2 - C + Y_1 &= \frac{\partial E}{\partial t} && \text{(iv)} \\
\eta(\delta - I_E) &= \frac{\partial \eta}{\partial t} && \text{(v)}
\end{aligned} \qquad (2.8)$$

Notice that from (ii) and (iii)

$$I_L = w_0 , \qquad (2.9)$$

which holds over the whole planning period. Thus, the farmer increases on-farm labor until marginal productivity equals off-farm wage. We can use this result to modify problem (2.1)(see Chambers and Lopez (1984)) by optimizing out L_1 from the income function. Such a modification simplifies subsequent analyses. The restructured income function becomes

$$\begin{aligned} I &= \max_{A,L_1} [\ \pi(P,W,L_1,A) - W_0L_1 - r(E)(AP_L - E)] \\ &= I(P,W,W_0,\phi,E) \end{aligned} \tag{2.10}$$

Now applying the envelope theorem to the new income function, we can derive on-farm labor input conditional on net equity as

$$L_1 = -I_{W_0}(\cdot) = -\pi_{W_0}(\cdot) \tag{2.11}$$

Substituting for L_1 in the original problem we have

$$\begin{aligned} &\mathrm{Max}_{C,L_2} \int_0^{\infty} U(C,H + I_{W_0} - L_2)\, e^{-\delta t} \\ \text{st:} \quad &\frac{\partial E}{\partial t} = I + W_0L_2 - C + Y_1 \\ &E(0) = E_0 \end{aligned} \tag{2.12}$$

The current value Hamiltonian for the restructured problem is given by

$$V = U(C,H + I_{W_0} - L_2) - \eta(I + W_0L_2 - C + Y_1) \tag{2.13}$$

which yields the following necessary optimality conditions

$$
\begin{aligned}
&U_C - \eta = 0 && \text{(i)}\\
&-U_l + \eta W_0 = 0 && \text{(ii)}\\
&I + W_0 L_2 + Y_1 - C = \frac{\partial E}{\partial t} = E' && \text{(iii)}\\
&\eta\,(\delta - I_E) = \frac{\partial \eta}{\partial t} = \eta' && \text{(iv)}
\end{aligned}
\tag{2.14}
$$

The first condition says that, along the optimal path, the farmer chooses consumption such that the marginal utility from consumption equals the current shadow price of net equity. Violation of this condition implies that farmers could benefit from using an alternative consumption-investment strategy.

Combining (i) and (ii) gives:

$$\frac{U_l}{W_0} = U_c\ , \tag{2.15}$$

which says that along the optimal path the utility of a dollar's worth of leisure - leisure time being priced at its opportunity price, W_0 - should equal the utility of a dollar's worth of consumption. This same condition would hold in static utility maximization.

Finally dividing both sides of (iv) by η gives:

$$\delta - I_E = \frac{\eta'}{\eta} \tag{2.16}$$

which says that the percentage change over time of the opportunity cost of net equity should equal net equity's net rate of return, made up of the discount rate or marginal cost of capital less the marginal income from net equity. For a nonrenewable resource, this condition implies the value of that resource decreases at the rate of the discount factor. Net equity, however, is productive, tending to dampen the rate of decline of its shadow value.

2.2 Steady-state and Stability

The first order conditions (2.14) can be reduced to a system of two equations. Taking time derivatives of (2.14(i)) and (2.14(ii)) gives

$$U_{CC}\frac{\partial C}{\partial t} + U_{Cl}\frac{\partial l}{\partial t} - \frac{\partial \eta}{\partial t} = 0 \tag{2.17}$$

$$-U_{ll}\frac{\partial l}{\partial t} - U_{Cl}\frac{\partial C}{\partial t} + \frac{\partial \eta}{\partial t}W_0 = 0 \tag{2.18}$$

Using these together with (2.14 (iii)) and (2.14 (iv)), one can substitute out terms involving η yielding

$$U_C(\delta - I_E) = U_{CC}\frac{\partial C}{\partial t} + U_{Cl}\frac{\partial l}{\partial t} \ , \tag{2.19}$$

and
$$-U_{ll}\frac{\partial l}{\partial t} + U_{Cl}\frac{\partial C}{\partial t} + W_0 U_C(\delta - I_E) = 0 \ . \tag{2.20}$$

Eliminating $\partial l/\partial t$ from (2.19) using (2.20) results in

$$\frac{\partial C}{\partial t} = \frac{U_C(U_{ll} - U_{Cl}W_0)(\delta - I_E)}{U_{CC}U_{ll} - U_{Cl}^2} \tag{2.21}$$

which together with the state equation (2.14(iii)) forms a two equation dynamical system in L_2, C, and E.

We need to go further and express the dynamical system only as a function of C, E, and the exogenous variables. Doing away with shadow the price of net equity allows the analysis to proceed on observable variables. To accomplish this, note that (i) and (ii) in (2.14) imply

$$-U_l + U_C W_0 = 0 \tag{2.22}$$

which allows leisure (l) to be expressed as a function of C and W_0. Thus, L_2 is

$$L_2 = H + I_{W_0} - l(W_0,C) \qquad (2.23)$$
$$= L_2(E,W,\phi,C) \; .$$

At steady-state, $\partial C/\partial t = \partial E/\partial t = 0$, so

$$I + W_0 L_2(E,C) + Y_1 - C = 0 \qquad (2.24)$$

and
$$\frac{U_C(U_{ll} - U_{Cl}W_0)(\delta - I_E)}{U_{CC}U_{ll} - U_{Cl}^2} = 0 \; . \qquad (2.25)$$

From the utility function properties discussed earlier, it follows that

$$R = \frac{U_C(U_{ll} - U_{Cl}W_0)}{U_{CC}U_{ll} - U_{Cl}^2} < 0 \; , \qquad (2.26)$$

which implies that at steady-state,

$$\delta - I_E = 0 \; . \qquad (2.27)$$

Obviously, at steady state E^*, investment is independent of consumption level, C. Thus in the C-E plane, the isocline $C' = 0$ is a vertical line (see FIGURE 2.1).

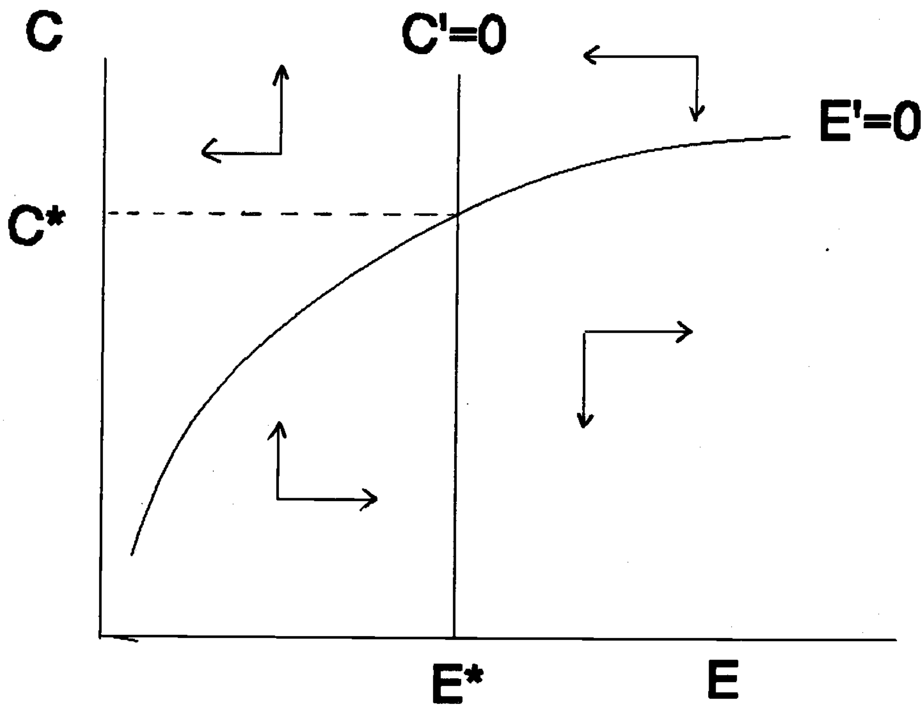

Figure 2.1 . Steady-State Equilibrium.

The slope of the isocline E' = 0 is

$$\left.\frac{d\,C}{d\,E}\right|_{E'=0} = -\frac{\partial E'/\partial E}{\partial E'/\partial C} = -\frac{I_E + W_0 L_{2E}}{W_0 L_{2C} - 1} \,. \tag{2.28}$$

From (2.23)

$$L_{2E} = I_{W_0 E} = -L_{1r}\, r_E \,. \tag{2.29}$$

If we assume that on-farm labor and land are substitutes, then L_{1r} is positive and since r(E) is a decreasing function of E, L_{2E} is positive. The assumption that labor and land are substitutes is reasonable since one would expect an increase in land use to lead to an increase in machinery use and hence to a reduction in per-acre on-farm labor. From (2.23) we have

$$L_{2C} = -\frac{d\ l(W_0,C)}{d\ C} = \left(\frac{-U_{Cl}+U_{CC}W_0}{-U_{ll}+U_{CL}W_0}\right) < 0 \tag{2.30}$$

since U_{cl} is assumed non negative. Therefore the slope of the E' = 0 isocline is positive, implying a monotonically increasing function and ruling out multiple equilibria.

The existence of the steady state can be proved by noting that the determinant of the steady state Jacobian (J_s) is nonzero as the following shows (Caputo, 1989):

$$|J_s| = \begin{vmatrix} \frac{\partial(\delta - I_E)}{\partial C} & \frac{\partial(\delta - I_E)}{\partial E} \\ \frac{\partial(I + W_0 L_2 - C + Y_1)}{\partial C} & \frac{\partial(I + W_0 L_2 - C + Y_1)}{\partial E} \end{vmatrix}$$

$$= \begin{vmatrix} 0 & -I_{EE} \\ (W_0 L_{2C} - 1) & (I_E + W_0 L_{2E}) \end{vmatrix} \tag{2.31}$$

$$= I_{EE}(W_0 L_{2C} - 1) > 0$$

To determine the stability of the dynamical system, we linearize (13) and (15) about the steady state by retaining the linear part of a Taylor series expansion (Caputo, p. 245).

$$\begin{pmatrix} C' \\ E' \end{pmatrix} = \begin{pmatrix} \frac{\partial C'}{\partial C} & \frac{\partial C'}{\partial E} \\ \frac{\partial E'}{\partial C} & \frac{\partial E'}{\partial E} \end{pmatrix}_{C'=E'=0} \begin{pmatrix} C - C^* \\ E - E^* \end{pmatrix} \tag{2.32}$$

$$= J_d \begin{pmatrix} C - C^* \\ E - E^* \end{pmatrix}$$

where borrowing Caputo's terminology, J_d is the dynamic Jacobian matrix. Thus,

$$\begin{pmatrix} C' \\ E' \end{pmatrix} = \begin{pmatrix} 0 & -RI_{EE} \\ (W_0 L_{2C} - 1) & (\delta + W_0 L_{2E}) \end{pmatrix} \begin{pmatrix} C - C^* \\ E - E^* \end{pmatrix} . \tag{2.33}$$

All the information one needs to determine local stability properties are contained in J_d; specifically in the characteristic roots or eigenvalues of J_d. These roots are the solution to the following quadratic equation:

$$|J_d - \lambda ID| = \lambda^2 - tr(J_d)\lambda + |J_d| = 0 , \tag{2.34}$$

where ID is the identity matrix and tr() is the trace operator.

The characteristic roots of equation (2.34) are

$$\lambda_1, \lambda_2 = \frac{tr(J_d) \pm \sqrt{tr(J_d)^2 - 4 \det(J_d)}}{2} . \tag{2.35}$$

Result (2.35) suggests the following relationships between λ_1 and λ_2:

$$\lambda_1 + \lambda_2 = tr(J_d) = \delta + W_0 L_{2E} > 0 \tag{2.36}$$

and

$$\lambda_1 \lambda_2 = det(J_d) = R\ det(J_d) = R\ I_{EE}(W_0 L_{2C} - 1) < 0\ , \tag{2.37}$$

the signs of which follow from previous discussion. The negative sign of the dynamic Jacobian determinant is very important because it ensures that we have real rather than complex characteristic roots, thereby ruling out fluctuating time paths of C and E. Also through (2.37) this property implies that one root is positive and the other negative. Furthermore, from (2.36) it follows that the positive root, which we can call λ_2, is greater than the absolute magnitude of the negative root λ_1. These characteristics suggest that our dynamic system has a "saddle-point" type equilibrium (see Possibility (iii) pp.642 in Chiang).

2.3 Steady-state Comparative Statics: General Formulae

From (13) and (15), using Cramer's Rule, the effects on long term consumption (C^*) and net equity (E^*), of exogenous variables ϕ_i appearing in the income function, are:

$$\frac{\partial C^*}{\partial \phi_i} = \begin{vmatrix} I_{E\phi_i} & -I_{EE} \\ -(I_{\phi_i}+W_0L_{2\phi_i}) & I_E+W_0L_{2E} \end{vmatrix} / \det(J_s)$$

$$= \frac{R}{\det(J_d)}\{I_{E\phi_i}(I_E+W_0L_{2E})-I_{EE}(I_{\phi_i}+W_0L_{2\phi_i})\} \tag{2.38}$$

and

$$\frac{\partial E^*}{\partial \phi_i} = \begin{vmatrix} 0 & I_{E\phi_i} \\ (W_0L_{2C}-1) & -(I_{\phi_i}+W_0L_{2\phi_i}) \end{vmatrix} / \det(J_s)$$

$$= -\frac{R}{\det(J_d)}(W_0L_{2C}-1)I_{E\phi_i} \ . \tag{2.39}$$

Obviously, without more structure on the income function, we cannot determine the effect of exogenous variables. This is deferred until we analyse the form of function I(.).

However, we can say something about the effect of the discount rate on long term consumption and net equity. In particular,

$$\frac{\partial C^*}{\partial(\delta)} = \begin{vmatrix} -1 & -I_{EE} \\ 0 & I_E+W_0L_{2E} \end{vmatrix} / \det(J_s)$$

$$= -\frac{R}{\det(J_d)}(I_E+W_0L_{2E}) < 0 \ , \tag{2.40}$$

and

$$\frac{\partial E^*}{\partial(\delta)} = \begin{vmatrix} 0 & -1 \\ (W_0L_{2C}-1) & 0 \end{vmatrix} / \det(J_s) \\ = \frac{R}{\det(J_d)}(W_0L_{2C}-1) < 0. \tag{2.41}$$

The signs of (2.40) and (2.41) follow from the previous discussion. Thus, an increase in discount rate decreases both long-run consumption and net equity. The long term negative discount rate effect on net equity is reasonable since high discount rates favor present consumption to the detriment of investing for the future. However, the result suggests, the short-run increase in consumption does not persist into the long term as the decrease in investment reduces future generations' disposable income. This argument becomes clearer, when in the following section, we discuss dynamic effects.

2.4 Local Comparative Dynamics: General

The approach taken here to investigate local comparative dynamic properties is to solve the linearized differential equation system and then determine the effects of exogenous variables on the solutions. Such an approach was taken by Caputo (1989) in his analysis of the qualitative properties of non-renewable resource models.

To solve the linearized system (2.33) we need to find the eigenvectors of the matrix J_d. These are given as solutions to the system of homogeneous equations:

$$\begin{pmatrix} \frac{\partial C'}{\partial C}-\lambda_i & \frac{\partial C'}{\partial E} \\ \frac{\partial E'}{\partial C} & \frac{\partial E'}{\partial E}-\lambda_i \end{pmatrix} \begin{pmatrix} Z^i_1 \\ Z^i_2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \quad i=1,2$$

or

$$\begin{pmatrix} -\lambda_i & -R\, I_{EE} \\ (W_0 L_{2C}-1) & \delta + W_0 L_{2E} - \lambda_i \end{pmatrix} \begin{pmatrix} Z_1{}^i \\ Z_2{}^i \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \quad i=1,2. \tag{2.42}$$

If we normalize $Z^i_2 = 1$, then (2.42) can be written as:

$$Z_1{}^i = \frac{\delta + W_0 L_{2E} - \lambda_i}{(W_0 L_{2C} - 1)}, \quad i=1,2. \tag{2.43}$$

The general solution of the linearized system is:

$$\begin{pmatrix} C(t,\phi) - C^* \\ E(t,\phi) - E^* \end{pmatrix} = a\, Z^1\, e^{\lambda_1 t} + b\, Z^2\, e^{\lambda_2 t}, \quad (a,\ b \text{ constants}) \tag{2.44}$$

$$\text{where } Z^i = (Z_1^{\,i}, Z_2^{\,i}) .$$

From the stability analysis, we have established that $\lambda_1 < 0 < \lambda_2$ which implies that for the convergent optimal trajectories, "b" has to be zero. Since we are interested in convergent optimal paths, the eigenvector of interest is that corresponding to λ_1. That vector is

$$Z^{1\prime} = (Z_1^{\,1}, Z_2^{\,1}) = \left(\frac{\delta + W_0 L_{2E} - \lambda_1}{-(W_0 L_{2C} - 1)} ,\ 1 \right), \tag{2.45}$$

where $Z_1^{\,1}$ is positive since, from previous discussion, $\delta + W_0 L_{2E} > 0$, $\lambda_1 < 0$ and $(W_0 L_{2C} - 1) < 0$. Being able to sign $Z_1^{\,1}$ is important because most of the comparative local dynamic effects depend on it.

Utilizing the initial condition in (2.12) and (2.44), at $t=0$ we have

$$E(0) - E^* = E_0 - E^* = a\, e^{\lambda_1 (0)} = a \tag{2.46}$$

Therefore, the solution to the linearized system is

$$\begin{pmatrix} C(t;\phi) \\ E(t;\phi) \end{pmatrix} = \begin{pmatrix} C^* \\ E^* \end{pmatrix} + (E_0 - E^*) \begin{pmatrix} Z_1 \\ 1 \end{pmatrix} e^{\lambda_1 t} , \tag{2.47}$$

which yields approximations to the optimal paths in the neighborhood of the steady-state.

The local effect of a change in any exogenous variable (ϕ_i) is determined by differentiating $C(t;\phi)$ and $E(t;\phi)$ with respect to the exogenous variable and evaluating the result at $E_0 = E^*$.

Consider the effect of beginning equity. Differentiating (2.47) with respect to E_0 we have:

$$\frac{\partial C(t;\phi)}{\partial E_0} = Z_1 e^{\lambda_1 t} \tag{2.48}$$

and

$$\frac{\partial E(t;\phi)}{\partial E_0} = e^{\lambda_1 t} . \tag{2.49}$$

Evaluating these derivatives at $t=0$ we have

$$\left.\frac{\partial C(t;\phi)}{\partial E_0}\right|_{t=0} = Z_1 > 0 \tag{2.50}$$

and $$\left.\frac{\partial E(t;\phi)}{\partial E_0}\right|_{t=0} = 1 \, . \tag{2.51}$$

These effects as t becomes large become:

$$\lim_{t\to\infty} \frac{\partial C(t;\phi)}{\partial E_0} = 0 \tag{2.52}$$

$$\lim_{t\to\infty} \frac{\partial E(t;\phi)}{\partial E_0} = 0 \tag{2.53}$$

The above results say that the moment beginning equity is increased, both consumption and net investment increase. Predictably, net investment increases by the same magnitude as the increase in beginning equity. However, consumption may increase more or less than the change in initial equity depending on the curvature properties of I- and U-functions incorporated in Z_1. It is easily seen through differentiation that the effects are monotonically decreasing, convex functions of time. Coupled with (2.52) and (2.53) this says that, after the initial increases in consumption and net investment, the effect of beginning equity decreases at an increasing rate until in the long-run effect is no longer felt.

In the ϵ-neighbourhood of the steady-state the effects on optimal paths of a discount rate increase are:

$$\frac{\partial C(t;\phi)}{\partial(\delta)} = \frac{\partial C^*}{\partial \delta} - \frac{\partial E^*}{\partial \delta} Z_1 \; e^{\lambda_1 t} \tag{2.54}$$

and $$\frac{\partial E(t;\phi)}{\partial \delta} = (1-e^{\lambda_1 t})\frac{\partial E^*}{\partial \delta} \; . \tag{2.55}$$

We know from (2.41) that the longrun effect of the discount rate on net investment is negative. It follows then from (2.55) that the local effect of the discount rate on the optimal net investment path is also negative. This is appealing since an increase in discount rate should make income generation in the future less attractive.

The effect of the discount rate on the consumption path, however, is not immediately deduced. From (2.40) and (2.41), and the fact that $Z_1 > 0$, the discount rate effect on the consumption path is indeterminant. Intuition suggests that, if we are to have a long-run decline in net investment, consumption needs to rise for some period. Indeed, evaluating (2.54) at $t=0$ this result is obtained. Thus, the new optimal consumption path lies above the old path in the periods just after the increase in discount rate, falls below the old path sometime in the medium run, and is below it in the longrun. The instant the discount rate is increased (e.g. the farmer is diagnosed with cancer), present consumption becomes more valuable, leading to an increase in consumption. An increase in consumption also implies an increase in leisure time allocation since the two are complements. Hence, on- and off-farm labor supply also decline. Meanwhile at $t=0$ net investment remains the same since investments cannot be readily liquidated. As $t \rightarrow \infty$ consumption has to decline to the new optimal path, and, as it so happens in this problem, this is below the old path. This implies that the decrease in planned net investment brought about by the increase in discount rate is less than the projected drop in the income steam.

Based on the structure we have postulated so far, this is all we can say on growth dynamics of the model. Further discussion requires a closer look at the form of the income function and its components.

2.5 The Farm Income Function.

In this section I develop the structure of farm income incorporating the dominant wheat farm program variables.

Assume wheat producers in each farm size class face a common production function

$$Y = Y(X, \tilde{A}^{o}, \tilde{A}^{r}, \tau, L_1) , \qquad (2.56)$$

which is a strictly concave increasing function of vector X, $\tilde{A}^{o}$, and $\tilde{A}^{r}$. X is a vector of variable inputs and $\tilde{A}^{o}$ and $\tilde{A}^{r}$ are planted acreages of owned and rented land, respectively. Variable τ is a technology shifter whilst L_1 is on-farm labor use. If A^r is less than zero, the farmer is renting out land while the opposite is true when the farmer rents in land.

The specification for Y(.), treating rented and owned operated land as separate variables, is adopted from Chambers and Phipps (1988). Such a specification recognizes the possibility that rented and owned lands may not be perfect substitutes. The reasons why this might be the case include the likelihood that rented land may demand different management practices because of its distance from the homestead. Also farmers are more likely to invest more in land improvements on owned rather than on rented land.

Assume further that the farmer has B acres as his operating wheat base acreage. To receive deficiency payments, the wheat program requires that farmers set aside a minimum portion of base acres, sB. If the farmer so chooses, he can set aside extra parcels of land up to a maximum of vB acres, the so-called "voluntary diversion". For voluntarily diverted land the farmer receives a per-acre payment of Go. On the minimum set aside land, per acre deficiency payments amount to:

$$DF = [P^T - \min(P^T, \max(P^S, P))] Y^o ,$$

where P is output market price, P^T is the target price, P^S is support price (i.e. loan rate), and Y^o is the program yield. Thus, if P^T greater than $\max(P^S, P)$, no deficiency payments are made.

The above provisions imply the following restrictions on area planted for participating farmers:

$$\tilde{A}^{o} \leq (1-s-v)B^{o} \quad \text{(i)}$$
$$\tilde{A}^{r} \leq (1-s-v)B^{r} \quad \text{(ii)} \qquad (2.57)$$
$$B = B^{o} + B^{r} \quad \text{(iii)}$$

where B^o and B^r are owned and rented base acreages.

At this point we make several simplifying assumptions to ensure interior solutions. These are

$$\text{A1.} \quad B^{o} = A^{o}$$
$$\text{A2.} \quad B^{r} = A^{r}$$

$$\text{A3.} \quad B^{o} + B^{r} = A^{r} + A^{o} > 0$$

Assumptions A1-A3 say that all operated land is included in base acreage.

A4. All program participants operate the voluntary diversion at the same level.

The overall implications of these assumptions are that restrictions (i) and (ii) in (2.57) hold with equality, and v is constant across farms.

Another important component of the income function is debt servicing. It is assumed that the farmer's gross equity is in the form of owned land. Define net equity (E) as

$$E \equiv A^{o} P_L - D \tag{2.58}$$

where $A^{o}P_L$ is gross farm equity and D is debt. Thus debt is equivalent to ($A^{o}P_L$ - E). As we discussed before, the interest charged on debt, to reflect bankrupcy risk, is a function of net equity. Thus, cost of debt servicing is

$$r\ D = A^{o}P_L\ (r_o+g(E)) - (r_o+g(E))\ E \tag{2.59}$$

At each point in time, and for each combination of net equity and on-farm labor input, the farmer seeks to maximize profit with respect to vector X, A^{o}, and A^{r}. Invoking assumptions A1 to A4, this can mathematically be characterized as

$$\begin{aligned} I = \max_{A^{r},A^{o}} \{ & (A^{o}+A^{r})[vG_o+(1-s-v)(P_T-P')Y_o] \\ & +\pi^{o}[W,P,A^{o}(1-s-v),A^{r}(1-s-v),L_1,\tau]-A^{r}q_o-A^{o}P_L r(E)+r(E)E\} \end{aligned} \tag{2.60}$$

where $\pi^{o}()$ is the restricted profit function, conditional on A^{o}, A^{r} and L_1; q_0 is the market land rental rate; W is a vector of variable input prices and P' is $\min(P^{T},\max(P^{S},P))$. $\pi^{o}()$ is the result of optimization

$$\pi^{o} = \max_X\ [PY - XW : Y \in Y(A^{o}(1-s-v),A^{r}(1-s-v),\tau,X,L_1)]\ . \tag{2.61}$$

Notice that we can change the above income optimization to a maximization with respect to planted, rather than overall, acreages and in the process combine government payment components into land rental and opportunity cost components. If we also invoke the condition that farmers use on-farm labor until its marginal productivity equals the off-farm wage rate, the income function becomes

$$\begin{aligned} I &= \max_{\tilde{A}^o,\tilde{A}^r}\{\pi^o(W,\tilde{A}^o,\tilde{A}^r,L_1,P,\tau)-\tilde{A}^r\bar{q}-\tilde{A}^o\bar{r}-L_1W_0+r(E)E\} \\ &= \pi(W,P,\tau,W_0,\bar{r},\bar{q}) + r(E)E \end{aligned} \tag{2.61}$$

where r^-, and q^- are adjusted land user costs. They are defined as

$$\begin{aligned} \bar{q} &= [q_0-vG_o-(1-s-v)(P^T-P^{\prime})Y^o]\,/(1-s-v), \quad \text{and} \\ \bar{r} &= [P_L(r_o+g(E))-vG_o-(1-s-v)(P_T-P^{\prime})Y^o]\,/(1-s-v)\ . \end{aligned} \tag{2.63}$$

The characterization of farm income outlined above has the following advantage. Since for any given level of net equity, r^- and q^- are constants, the function $\pi()$ has the same properties as any well behaved unrestricted indirect profit function. This is important for the purposes of postulating a functional form for I() and deriving net-equity-dependent input and output demand and supply relationships. In particular, we can use Shepard's and Hotelling's Lemmae.

2.6 Non-Participant Income

The program non-participant, as opposed to the participant, is not constrained by acreage set-aside requirements and so can plant all available land. However, the non-participant does not receive the revenue enhancing benefits of farm programs. Non-participant's income can be characterized as:

$$\begin{aligned} I^n &= \max_{A^o,A^r} [\pi^o(W,P,A^o,A^r,\tau,L_1)-W_o-A^r q_o-r(E)P_L A^o+r(E)E] \\ &=\pi(W_o,W,\tau,q_o,\tilde{r},P)+r(E)E \end{aligned} \quad (2.64)$$

where $r^{\sim} = r(E)P_L$. The interesting thing to note is that the income functions for the participant (I) and for the non-participant (I^n) differ only in the per-acre user costs of rented and owned land. Because q_0 and $r^{\sim}$ are contained in participant user costs q^{-} and r^{-}, deducing the qualitative properties for the participant problem also reveals those for the non-participant.

2.7 Steady-state Comparative Statics.

The discussion on general steady-state comparative statics in Section 2.3 (see equations 2.38 and 2.39) identifies the effects on the income function essential to complete my discussion on the qualitative effects of individual exogenous variables on long-run net equity and consumption;

I_{ϕ_i} , $I_{E\phi_i}$, and $I_{W_o\phi_i}$.

Appendix I derives the nature of these effects which are summarized in Table 2.1. Substituting the results of appendix I in equations (2.38) and (2.39) gives the longrun effects of each exogenous variable on consumption and net equity. These are reported in Table 2.2. In the following I discuss each long-run effect in turn.

As reported in Table 2.2, an increase in the paid diversion rate (G_o) leads to an increase in both long-run consumption and net equity, provided on-farm labor and owned land are substitutes. If the farmer is a program participant, increasing the diversion payment rate does not require a decrease in production, but always increases government program payments; hence, income will always be increased. Increased income means there is more money available to allocate between consumption and investment. I treat program participation as predetermined so changes in the diversion payment must be small enough not to effect program participation. Also, part of diversion payments are for additional voluntary set-asides which reduce the planted acreage.

The effect of the non-paid set-aside, s, is less straight forward. If the negative of the own price elasticity of owned land demand (σ) exceeds the ratio of program adjusted owned land user price to the sum of program adjusted owned land user price and per planted acre deficiency payment rate, K_s (defined in Appendix I), and labor and land are substitute variables, then an increase in s will lead to a decrease in both long-run consumption and net equity. If different

Table 2.1. Summary of Exogenous Variable Effects on Income.

	$I_{\phi E}$		$I_{\phi wo}$		I_ϕ
Variable ϕ	$\sigma < k_\phi$	$\sigma > k_\phi$	subst L,A	Compl L,A	
G_o	+	+	+	-	+
s	+	-	-	+	-
v	+	-	-	+	-
P^T	+	+	+	-	+
P	-	-	-	-	+
Y^o	+	+	+	-	+
r_o	+	+	-	+	-
P_L	+	-	-	+	-
q_0	0	0	-	+	-
W	-	+	+	-	-

Each cell in Table 2.1 shows the direction exogenous variable effect.

L and A, respectively stand for family labor and land.

"Subst" and "comp" are short for substitutes and complements, respectively.

σ is the own the negative of the own price elasticity of demand for owned land.

$K\phi$ are critical values across which direction of effect may change. These are defined in Appendix I.

Table 2.2. Longrun Effects of Exogenous Varibles on Consumption and Net Equity.

	C^*		E^*	
Variable	L,A Subst	Otherwise	$\sigma < k_\phi$	$\sigma > k_\phi$
G_o	+	?	+	+
s	- if $\sigma>k_s$	?	+	-
v	- if $\sigma>k_v$	?	+	-
P^T	+	?	+	+
P	?	?	-	-
Y^o	+	?	+	+
r_o	-	?	-	-
P_L	- if $\sigma>k_{PL}$	?	+	-
q_0	?	?	+	+
W	-	?	+ X,A sub - X,A comp	+ X,A sub - X,A comp

a. See footnotes to Table 2.1.

farm size classes have different technologies, non-paid percent set-aside (s) can have opposing growth effects on farms in different size classes.

Two other instruments, voluntary percent set-aside (v) and land purchase price (P_L), yield similar longrun effects on consumption and net equity, with the exception that the switch in direction of effects occurs at different levels of σ. In the case of voluntary percent set-aside, the long term effects switch from negative to positive when σ falls below K_v (defined in Appendix I as the ratio of adjusted owned land use cost to adjusted owned land use cost plus per-planted-acre deficiency payments less per-planted-acre paid diversion payment rate). In the case of land purchase price, the switching point is K_{PL}, the ratio of the product of adjusted owned land use cost and proportion of planted land to loan interest rate.

The effect of an increase in percent voluntary diversion (v) should be the same as that of unpaid required percent diversion since both parameters reduce planted acreages and increase government payments. If σ is very high, the government-payment-increasing effect of v can be less than its enterprise-profit-reducing effect, giving a net negative effect on income, and hence on consumption and investment. The opposite occurs when σ is low. In an analogous way, P_L affects income in two opposing ways. P_L enters the income function in the adjusted land use cost. An increase in P_L leads to a decrease in owned land demand. P_L also enters the income function through cost of debt servicing, where it increases the value of assets and hence lowers "r," the unit cost of debt. What the comparative steady-state statics show is that at low values of σ, the short-run profit reducing effect of a higher P_L are outweighed by P_L's asset-value-increasing effect. The opposite is true at higher σ values.

Yet another exogenous variable with an indeterminate effect on income is output price. If $P^T > P > P^S$, then P will have a negative effect on government payments since it reduces the deficiency payment rate. Since P has a positive effect on enterprise profit, the net effect on income can be positive or negative. However, it seems plausible to think that the farmer gets most of his income from farming and that the effect on profit outweighs the negative effect on government payments. If $P^T < \max(P, P^S)$ no deficiency payments are made, hence an increase in P only increases profits. The effect on long-run net equity is positive because with increased P, the income per unit of net equity rises, making the farmer more willing to invest in land. However, an increase in on-farm income also increases demand for on-farm family labor, which reduces off-farm earnings. How disposable income is affected determines whether long-run consumption will be higher or lower than at current price, P.

Land rental rate, q_0 has a positive effect on long-run net equity and an indeterminate effect on long-run consumption. The positive effect on net equity is due to rented land being substituted for owned land in production. An increase in q_0 encourages farmers to invest in land. Furthermore, off-farm income should decrease as the farmer substitutes his labor for rented land. An increase in rent also increases costs to the farmer, which reduces his profits.

This immediately translates into less disposable income. Thus, one would expect isocline C' = 0 to shift to the right and isocline E' = 0 to shift downward. Depending on the slope of the E' = 0, the long-run effect on consumption can be positive or negative. The effect on long-term net equity on the other hand is clearly positive.

Deficiency payments and income are positively related to both target prices (P^T) and program yield (Y^0) provided P^T is greater than max (P, P^S). Otherwise, neither variable has any effect on deficiency payments and thus income. If P^T > max (P, P^S), an increase in P^T or Y^0 encourages investment in owned land, which increases off-farm income as family labor is substituted out of farming and as the farm takes on machinery to capture scale effects. This is reflected in a shift to the right in both the E' = 0 and C' = 0 isoclines; equilibrium long-run consumption and net equity both rise.

An increase in the risk free rate of interst (r_0) has a negative effect on both long-run consumption and net equity. An increase in r_0 raises the opportunity cost of using owned land through the adjusted land use cost and also increases the cost of servicing debt. This adversely affects investment, reducing future equilibrium net equity. Rented land also becomes a relatively cheap substitute for owned land,increasing equilibrium rented land and dampening the farm labor demand. The negative effect on current income and the lower future income generation implied by lower investment mean that long-term consumption would decrease with an increase in r_0.

Finally, we look at the long-run effects of other farm input prices. As Table 2.2 shows, an increase in the price of input X_i, say W_i, leads to a decrease in long-term consumption and an increase in long-term net equity, provided X_i and land are substitute inputs. If they are complements, the net equity effect is negative. This result can be explained as follows. If X_i and land are substitutes, an increase in W_i encourages investment in the now relatively cheaper land, leading to a shift to the right in the $C' = 0$ isocline. In addition, if X_i and labor are substitutes, this would lead to a decrease in off-farm labor earnings, as farmers devote more time to on-farm activities. The decrease in both on-farm and off-farm income shifts $E' = 0$ to the left, resulting in lower long-run consumption. The opposite is true when X_i and land are complements.

The analysis just completed dealt with shifts in long-run equilibria. In the next section we look at the transition from the short-run to the long-run by evaluating the effects of exogenous variables on optimal consumption and net equity time paths in the ϵ-neighborhood of the steady-state.

2.8 Local Comparative Dynamics

Consider the local dynamic effect of paid diversion rate G_0 in the neighborhood of the equilibrium. Differentiating (2.47) with respect to G_0 and evaluating the result at $E_0 = E^*$ we have:

$$\frac{\partial E(t;\phi)}{\partial G_0} = \frac{\partial E^*}{\partial G_0}(1 - exp(\lambda_1 t)) > 0 . \tag{2.65}$$

$$\frac{\partial C(t;\phi)}{\partial G_0} = \frac{\partial C^*}{\partial G_0} - \frac{\partial E^*}{\partial G_0} \cdot exp(\lambda_1 t) >/\leq 0 . \tag{2.66}$$

Evaluating these derivatives at t = 0, we get the initial response on consumption and net equity as:

$$\frac{\partial C(t;\phi)}{\partial G_0}\Big|_{t=0} = -\frac{\partial E^*}{\partial G_0} Z_1 < 0 \tag{2.67}$$

$$\frac{\partial E(t;\phi)}{\partial G_0}\Big|_{t=0} = 0 . \tag{2.68}$$

In the limit, as $t \rightarrow \infty$, these effects become:

$$lim_{t\to\infty} \frac{\partial E(t;\phi)}{\partial G_0} = \frac{\partial E^*}{\partial G_0} \quad and \quad lim_{t\to\infty} \frac{\partial C(t;\phi)}{\partial G_0} = \frac{\partial C^*}{\partial G_0} . \tag{2.69}$$

Twice differentiating these effects with respect to time, we find that effects of G_0 on consumption and net equity are both monotonic increasing concave functions of time.

Discussion of the above effects is better accomplished with the use of phase diagrams (see Figure 2.2). The instant G_0 is increased, net farm income, which can be considered as economic rents to land, rises. This increases famers' desire to hold more owned land, shifting the optimal separatix from hh to h'h' in Figure 2.2. Since, in the very short-term, land is fixed, there is no change in net investment. What the farm can do is reduce consumption in anticipation of future investment. Depending on the value of Z_1, the initial drop in consumption can put it below the new optimal separatix as in Figure 2.2(a), or above the new optimal separatix as depicted in 2.2(b). This explains the indeterminacy of the effect of G_0 on the consumption path. In the medium term, the farmer invests in land, reducing its shadow price as the new long-term equilibrium is established. As the shadow price of land decreases, the marginal utility of consumption increases in relative terms, so that consumption increases to its new long-run equilibrium as $t \rightarrow \infty$.

The effect of s, v, and P_L on optimal paths in the ϵ-neighborhood of the steady-state can be studied together since they have similar effects. It will suffice to discuss only one of these terms. Let us take, for instance, the effect of s. Differentiating (2.47) with respect to s and evaluating the result at E_0 = E^* we get:

$$C_S(t;\phi) = C_S^* - E_S^* \cdot Z_1 \, exp(\lambda_1 t) >/\leq 0 \,, \tag{2.70}$$

$$and \quad E_S(t;\phi) = E_S^*(1 - exp(\lambda_1 t)) > 0 \quad if \; \sigma < K_S \tag{2.71}$$

$$< 0 \; if \; \sigma \; > K_S \; .$$

Evaluating these derivatives at t = 0 we have

$$C_S(t=0;\phi) = -E_S^* Z_1 > 0 \quad if \quad \sigma > K_S \, , \tag{2.72}$$

$$< 0 \quad if \quad \sigma < K_S \, ,$$

$$and \qquad E_S(t=0;\phi) = 0. \tag{2.73}$$

Again, as $t \rightarrow \infty$ the right-hand side (RHS) expressions reduce to their long-run values. If $\sigma > K_S (< K_S)$ both effects' changes with time can be characterized by monotonic decreasing (increasing) convex (concave) functions of time.

Now consider the case when $\sigma > K_S$. In this case, following arguments in the preceding section, an increase in s will reduce net farm income because the enterprise profit reducing effect outweighs the government payment increasing effect. Thus, owned land loses economic rents and consequently its shadow price also drops. In anticipation of divestment from land, the farmer raises his consumption. Since land is fixed in the short term, there is no movement in net equity. As $t \rightarrow \infty$ and the farmer sells land, both consumption and net equity decrease toward the new and lower equilibrium, following an adjustment path such as ABC in Figure 2.3(a).

If on the other hand, $\sigma < K_S$ the negative effect of s on enterprise profit is outweighed by the government payment increasing effect and C' = 0 shifts to

(a)

(b)

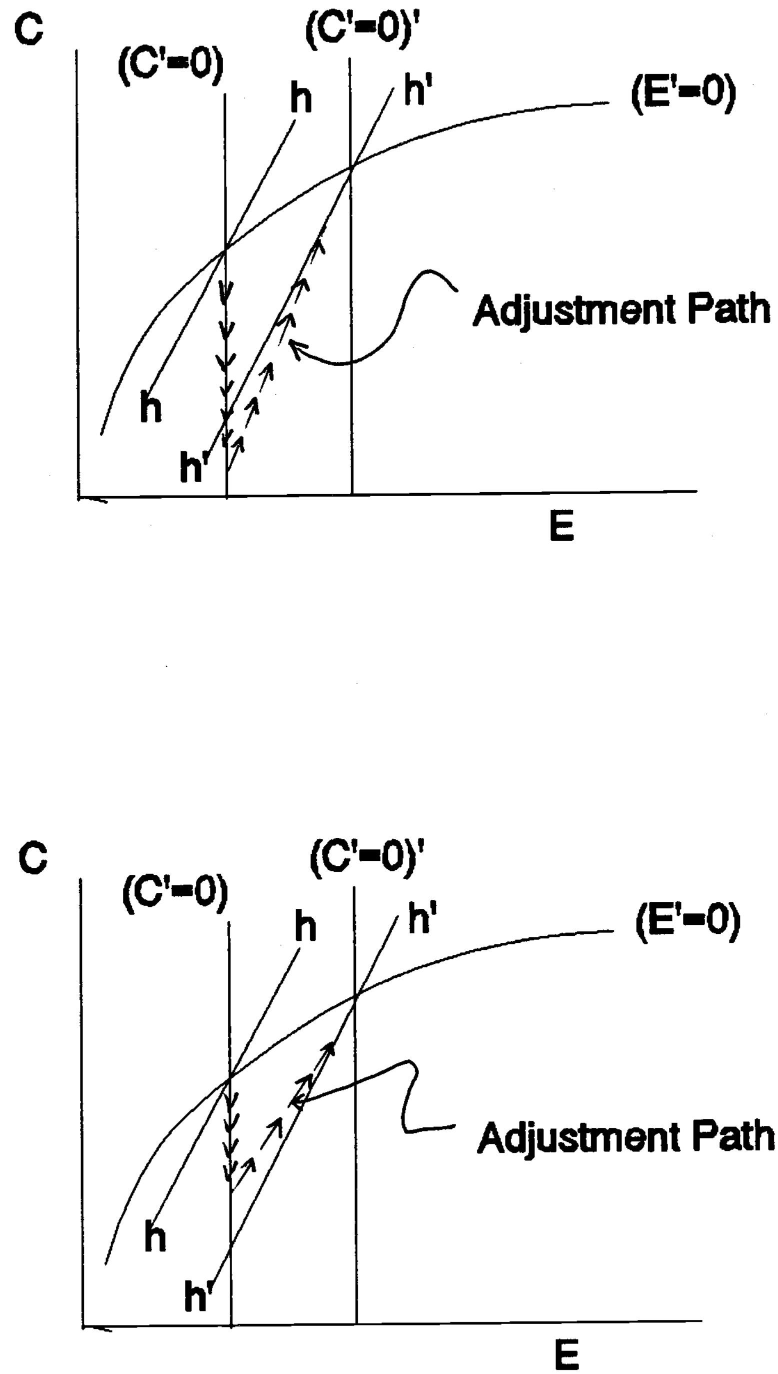

Figure 2.2 . Dynamic Adjustment to Increase in Go.

(a)

(b)

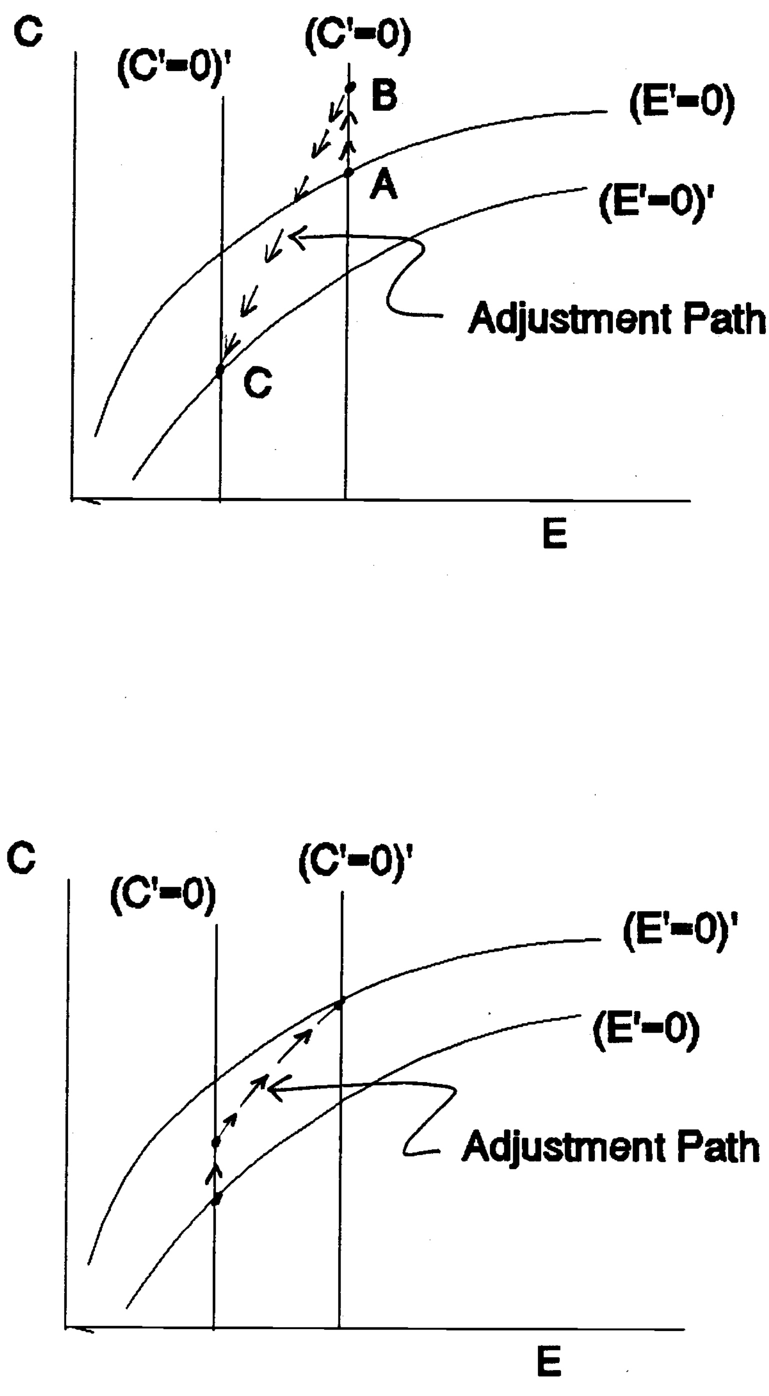

Figure 2.3 . Dynamic Adjustments to Increase in S.

the right. The ensuing increase in owned land can have a negative impact on off-farm income which, if larger than the increase in on-farm income due to new investments, can shift the E' = 0 isocline down. Figure 2.3(b) assumes that the on-farm income effect outweighs the off-farm earnings effect. Again, the initial adjustment is felt in consumption, which increases sharply the instant s is increased and then increases more slowly toward the new optimal path as the farmer invests in new land.

The arguments for the effects of v and P_L proceed in exactly the same way as for s except that we replace K_S by K_V and K_{PL}, respectively.

P^T and Y^0 affect the deficiency payments rate positively while effective price P' affects it negatively. Since these variables enter the income function through the deficiency payment rate, one need only analyze the effects of the deficiency payment rate (G_1) on paths to reveal the effects of these variables.

Differentiating (2.47) with respect to G_1:

$$C_{G_1}(t;\phi) = C^*_{G_1} - E^*_{G_1} \cdot Z_1 \cdot exp(\lambda_1 t) >/< = 0 \ , \qquad (2.74)$$

$$and \ \ E_{G_1}(t;\phi) = E^*_{G_1}(1 - exp(\lambda_1 t)) > 0 \ . \qquad (2.75)$$

As it turns out, these results are similar to effects of the paid land diversion rate discussed above. That is, G_1 increases the marginal returns to investment, which decrease consumption in the short term. As $t \rightarrow \infty$, and the farmer actually invests, consumption rebounds from its short-term drop due to the increase in the scale of the farmer's operation and increase in relative marginal utility from consumption as investment approaches its optimal path. Depending on the magnitude of Z_1 the new consumption path can lie above or below the old path as illustrated in Figure 2.2.

W and q_0, representing variable farm inputs, have common effects on optimal paths. Consider the effect of W. If labor and land are substitutes and input X and land are substitutes, differentiating (2.47) with respect to W gives:

$$C_W(t;\phi) = C_W^* - E_W^* \cdot Z_1 \cdot exp(\lambda_1 t) < 0 \tag{2.76}$$

and

$$E_W(t;\phi) = E_W^*(1 - exp(\lambda_1 t)) > 0 \,. \tag{2.77}$$

Which says that the new optimal path, after an increase in W, would lie below the old path in the case of consumption and above the old path in the case of net investment. If X and A are complements, then the new path for net investment would lie below the old optimal path in the neighborhood of the steady state. This makes economic sense since if X and A are substitutes, an increase in the price of X increases marginal profitability of net investment relatively. As we have discussed with the other effects, in the short-term land is fixed such that we only begin to see the net investment change in the medium to long term.

The effect of an increase in the risk free cost of capital, r_0 is opposite to that of G_0. The latter means that we would expect an increase in r_0 to have a negative impact on the optimal path of net investment and an indeterminate effect on consumption path. This is easy to see since an increase in r_0 increases the cost of new debt, which discourages investment. Also, the increase in cost of capital decreases income directly and this has an immediate effect on consumption through the dynamic budget constraint.

CHAPTER III

EMPIRICAL MODEL

The implications of the farm growth model discussed in Chapter II are here investigated empirically using an approach prevalent in adjustment-cost-studies. An example of this approach is Bernt, Fuss, and Weaverman (1978), who investigate investment in energy industries. Recent studies of agricultural investment using the same approach are by LeBlanc and Hrubovack (1986) and by Chambers and Lopez (1984). Chambers and Lopez exhaustively develop the theoretical underpinnings of the approach.

The model estimated in this study follows the development in Lopez (1985) on investment in the Canadian food processing industry. In his study, the first-order conditions of short-run farm income maximization conditional on net equity are estimated in conjunction with the discretized first-order conditions of the dynamic model (i.e. equation (2.14(iii)) and (2.21) in Chapter II). Such an estimation yields parameter estimates for the technology and utility of capital which can be used to simulate long-run and dynamic effects of exogenous variables on consumption and net equity accumulation. The following sections build equations to accomplish such a task. To do that, we need to specify functions to represent the farmers' utility, cost of capital, and technology.

3.1 Utility

The utility function chosen for this study is the logarithmic function; a monotonic transformation of the popular Cobb-Douglas functional form,

$$U = \alpha \, ln \, C + (1 - \alpha) ln \, l \, . \tag{3.1}$$

There are both advantages and disadvantages in using this function.

First, let us consider the disadvantages. The Cobb-Douglas function restricts the elasticity of substitution between consumption and leisure to be unity. There is no plausible reason why the elasticity of substitution should be a constant, let along unity. If such a function is used in static demand analysis, it would restrict the demand for consumption to be independent of the price of leisure. As Deaton and Muellbauer (1980, p. 314) argue, its use in intertemporal life-cycle consumption studies can lead to overestimating intertemporal substitution effects.

Despite the abovementioned weakness of the Cobb-Douglas function, it is a widely used function. It satisfies all the basic requirements of a well-behaved utility function and the assumptions on which the theoratical model of Chapter II is based. The main advantage of the Cobb-Douglas function is that it has few parameters to estimate. This is a major consideration given the complexity of the model. Yet another advantage in the context of this study is that, from optimality conditions 2.14(i) and 2.14(ii) in Chapter II, we can express explicitly leisure as a function of consumption and off-farm wage rate:

$$U_c W_0 = U_l \tag{3.2}$$

$$\frac{\alpha W_0}{C} = \frac{(1-\alpha)}{l} \Rightarrow l = \frac{(1-\alpha)}{\alpha}\frac{C}{W_0} \;. \tag{3.3}$$

3.2 Technology

Recall from Chapter II, that income (I) can be specified as:

$$I = \pi + r(E) \cdot E \tag{3.4}$$

where π is the maximized profit subject to a given technology. Lau (1978) showed that if a firm is in a competitive market and its production function satisfies the concavity property, there is a one-to-one correspondence between the production function and a convex indirect profit function. This allows recovery of the primal technology properties from estimates of a well-behaved indirect profit function.

A well-behaved indirect profit function (henceforth just profit function) is one that satisfies the following properties (see Birchenhall and Grout, 1984):

(i) $$\textit{If } P^1 \geq P, \textit{ then } \pi(P^1,W) \geq \pi(P,W) \tag{3.5}$$

and (ii)

$$If\quad W^1 \geq W,\ then\ \pi(P,W^1) \leq \pi(P,W) \tag{3.6}$$

That is, profit must be nondecreasing in output prices and nonincreasing in input prices. This is the so-called monotonicity property.

(iii)

$$\pi(\alpha p,\ \alpha W) = \alpha\pi(P,\ W),\ \alpha > 0. \tag{3.7}$$

The profit function is homogeneous of degree one in input and output prices.

(iv)

$$\pi(\alpha P + (1 - \alpha)P',\ W) \leq \alpha\pi(P,\ W) + (1 - \alpha)\ \pi(P',\ W). \tag{3.8}$$

(v)

$$\pi(P,\ \alpha W) + (1 - \alpha)W') \leq \alpha\pi(P,\ W) + (1 - \alpha)\ \pi(P,\ W'). \tag{3.9}$$

These two properties say that the profit function is convex in input prices and in output prices.

(vi)

$$\pi_{PW} = \pi_{WP} \quad and \quad \pi_{W_iW_j} = \pi_{W_jW_i}\,. \tag{3.10}$$

which is the symmetry result from Young's Theorem.

Flexible functional forms for the dual have the advantage of not placing restrictions on the technology. One such flexible function is the normalized quadratic profit function, which is a second-order expansion approximation to the true normalized profit function. The normalized quadratic profit function has become a popular choice in supply and input demand studies because it yields supply and demand equations that are linear in parameters and demand equations that are in addition linear in the variables. This is very attractive because it reduces estimation burden. The other advantage is that the normalized quadratic profit function is self dual. Thus, its underlying technology is also quadratic; which means that if we are interested in the production function, we can recover its parameters from estimation of the profit function. Also, as we will see later in this chapter, restricting the profit function to satisfy global convexity is easy with the normalized quadratic because it yields a constant Hessian matrix.

Following (LeBlanc and Hrubovcak 1986, p. 769), the normalized unrestricted quadratic profit function, appended for technological change, can be specified as:

$$\frac{\pi}{P} = a_c + \sum_{i=0}^{n} a_i \frac{W_i}{P} a_r \frac{r'}{P} + a_q \cdot \frac{q'}{P}$$

$$+ \sum_{i=0}^{n} \sum_{j \neq i} a_{ij} W_i \frac{W_j}{P^2} + \frac{r'}{P} \sum_j a_{ri} \frac{W_i}{P} + \frac{q'}{P} \sum_i a_{qi} \frac{W_i}{P}$$

$$+ a_{qr} \frac{r'q'}{P^2} + \frac{1}{2} \sum_i a_{ii} \left(\frac{W_i}{P}\right)^2 + \frac{1}{2} \left(a_{rr} \left(\frac{r'}{P}\right)^2 + a_{qq} \cdot \left(\frac{q'}{P}\right)^2\right)$$

$$+ a_t \cdot t + \frac{t}{P} \left[a_{tr} \cdot r' + a_{tq} \cdot q' + \sum_i a_{ti} \cdot W_i\right] \qquad (3.11)$$

where $a_{ij} = a_{ji}$, i.e., the symmetry requirement of profit functions, is imposed. Note also that the normalization (in this case by output price) imposes the homogeneity requirements.

Applying Hotelling's Lemma to the above function by taking first derivatives with respect to normalized prices, we get:

$$-X_i = a_r + a_{ii}\frac{W_i}{P} + \sum_{j \neq i} a_{ij}\frac{W_j}{P} + a_{ri}\cdot\frac{r'}{P} + a_{qi}\frac{q'}{P} + a_{ti}t \ ,$$

$$\forall_i = 1,n \qquad (3.12)$$

$$-A^0 = a_q + a_{rr}\frac{r'}{P} + a_{qr}\cdot\frac{q'}{P} + \sum a_{rj}\frac{W_j}{P} + a_{tr}\cdot t \ , \qquad (3.13)$$

and

$$-A^r = a_q + a_{qq}\frac{q'}{P} + a_{qr}\cdot r' + \sum a_{qj}\frac{W_j}{P} + a_{tq}\cdot t \qquad (4.14)$$

where X_i is the quantity of input i demanded and A^0 and A^r are quantities of owned and rental land demanded for planting.

The supply quantity is recovered from the following relationship (see Yotopolus, 1972):

$$Y = (\pi + \Sigma W_i X_i + r'\cdot A^0 + q'\cdot A^r)/P \qquad (3.15)$$

where π, X_i, A^0, and A^r are optimal amounts. This yields supply as the quadratic relationship

$$Y = a_c + a_t \cdot t - \frac{1}{2} \sum_i a_{ii} \left(\frac{W_i}{P} \right)^2 - \sum_i \sum_{j \neq i} a_{ij} \frac{W_i W_j}{P^2} , \qquad (4.16)$$

We assume (see Chapter II, Section 2.5) the farmer's technology does not change with government program participation. This implies that differences in income between participation and no participation are due to differences in r′ and q′, area planted and government payments. Also, it implies the profit function parameters would be the same regardless of participation.

The general form of the supply and demand equations is:

$$Z = Z^p \cdot F + Z^{np} (1 - F). \qquad (3.17)$$

Superscripts p and np designate participant and nonparticipant, and F is an indicator variable that takes the value one if the farmer participates in government programs and zero if he does not. Using this general form, the estimating equations for the supply and input demand system become:

$$X_i = -[a_i + a_{ii}\frac{W_i}{P} + \sum_{j\neq i} a_{ij}\left(\frac{W_j}{P}\right) + a_{ti}\, t$$

$$+ \frac{a_{ri}}{p}\left(\bar{r}F + \not{r}(1 - F)\right) + \frac{a_{qi}}{p}\left(\bar{q}F + (1 - F)\, q_0\right) \tag{3.18}$$

$$i = 1, \ldots, n$$

$$A^0 = -\left(a_r \sum_j a_{rj}\frac{W_j}{P} + a_{tr}\cdot t\right)\left(\frac{F}{1 - S - V} + 1 - F\right)$$

$$- \frac{F}{(1 - S - V)}\left[a_{rr}\cdot\frac{\bar{r}}{p} + a_{qr}\cdot\frac{\bar{q}}{P}\right] - (1 - F)\left[a_{rr}\frac{\not{r}}{P} + a_{qr}\frac{q_0}{P}\right] \tag{3.19}$$

$$A^r = -\left(a_q + \sum_j a_{qj}\frac{W_j}{P} + a_{tq}\cdot t\right)\left(\frac{F}{1 - S - V} + 1 - F\right)$$

$$- \frac{F}{(1 - S - V)}\left[a_{qr}\frac{\bar{r}}{p} + a_{qq}\frac{\bar{q}}{P}\right] - (1 - F)\left[a_{qr}\frac{\not{r}}{P} + a_{qq}\frac{q_0}{P}\right] \tag{3.20}$$

$$Y = a_C + a_t\cdot t - \frac{1}{2}\sum a_{ii}\left(\frac{W_i}{P}\right)^2 - \sum_i\sum_{j\neq i} a_{ij}\frac{W_i W_j}{P^2}$$

$$- F\cdot\left[\frac{1}{2}\left(a_{rr}\left(\frac{\bar{r}}{P}\right)^2 + a_{qq}\left(\frac{\bar{q}}{P}\right)^2\right) + \frac{\bar{r}}{P}\sum_j a_{rj}\frac{W_j}{P} + \frac{\bar{q}}{P}\sum a_{qj}\frac{W_j}{P}\right]$$

$$- (1 - F)\left[\frac{1}{2}\left(a_{rr}\left(\frac{\not{r}}{P}\right)^2 + a_{qq}\left(\frac{q_0}{P}\right)^2\right) + \frac{\not{r}}{P}\sum_j a_{rj}\frac{W_j}{P} + \frac{q_0}{P}\sum_j q_{qj}\frac{W_j}{P}\right] \tag{3.21}$$

As discussed in Chapter II, (1-s-v) is the fraction of total operated land that is planted; $\overline{r}$ and $\overline{q}$ are owned and rented land program adjusted prices, and r and q_0 are respectively the nonprogram adjusted land prices.

3.3 Cost of Capital

We adopt Chambers' specification of effective interest rate (see Chambers, 1985, p. 393):

$$r = r* + \phi(E) \tag{3.22}$$

where r* is the risk-free rate of return and ϕ is such that:

$$\phi(E) \geq X\ 0\ ,\ \ \phi'(E) \leq 0 \quad and \quad \lim_{E\to\infty} \phi''(E) = 0\ , \tag{3.23}$$

which implies that $\phi''(E) \geq 0$. A function which possesses the above properties and has the added advantage of few estimating parameters is:

$$r = g_0 + \frac{g_1}{E}\ , \qquad g_0 \ \ and\ g_1 \geq 0. \tag{3.24}$$

3.4 Farm Program Adjusted Prices

In this section we expand the structure of farm programs. We do this by splitting the paid diversion into the part which is voluntary and that which is required. Conservation costs are added after the 1980 Farm Legislation Bill. Government payments per planted acre become:

$$GVT = \left(\frac{V\% \cdot VP + S1\% \cdot SP - CONSV + (1 - S1\% - S2\% - V\%)(P^{T} - P')Y^{0}}{(1 - S1\% - S2\% - V\%)} \right) \quad (3.25)$$

where

V% = Voluntary diversion percentage

VP = Per acre rate of payment for voluntary diversion

S1% = Required paid diversion percentage

SP = Payment rate on required paid diversion acres

S2% = Required nonpaid diversion percentage

CONSV = Per acre cost of conservation required on set aside land;

and as before P^T is target price and $P' = \min(\max(P^S, P), P^T)$. Thus PLT = (1 - S1% - S2% - V%) is the proportion of operated land that is planted by a participating farmer. The changes do not in any way change the qualitative results of Chapter II.

This specification of government programs implies that program-adjusted owned and rented land use prices become:

$$\bar{r} = (r \cdot PL - PLT \cdot GVT)/PLT \qquad (3.26)$$

$$\text{and} \qquad \bar{q} = (q_0 - PLT \cdot GVT)/PLT. \tag{3.27}$$

We know that unadjusted use prices are $\bar{r} = r \bullet P_L$ and q_0 = rental rate. This completes the specification of input demand and supply functions.

3.5 Equity and Consumption Adjustment Equations

With income, utility, and cost of capital specified, we can now get explicit representations of the investment and consumption adjustment equations. Before we can econometrically estimate these, however, we need to discretize equations (2.14(iii)) and (2.21) of Chapter II by writing them as appropriate difference equations. Thus we have:

$$\Delta E = I + W_0 L_2 + Y_1 - C_t \tag{3.28}$$

$$\text{and} \qquad \Delta C = -C_t(\delta - I_E) \, . \tag{3.29}$$

Given the logarithmic utility function. Off-farm labor L_2 can be specified as

$$L_2 = H - L_1 - l \tag{3.30}$$

If we assume total time available to a farmer is proportional to the size of the farm family (hhold), then

$$H = b_0 \cdot hhold. \tag{3.31}$$

From the input demand system just specified:

$$L_1 = -(a_0 + a_{00}\frac{W_0}{P} + \sum_{j=1}^{n} a_{0j}\frac{W_j}{P} + a_{t0}\,t$$

$$+ \frac{a_{r0}}{P}(\bar{r}F + r\,(1 - F)) + \frac{a_{q0}}{P}(\,\bar{q}F + (1 - F)\,q_0\,)\,)\,. \tag{3.32}$$

Therefore, off-farm labor demand is:

$$L_2 = b_0 \cdot hhold - L_1 - \frac{(1 - \alpha)}{\alpha}\frac{C}{W_0}\,. \tag{3.33}$$

Income from farming (I) becomes:

$$I = \pi + r \cdot E - FIXED\,, \tag{3.34}$$

where FIXED is appended to reflect fixed costs. Differentiating this function with respect to E we get

$$I_E = \frac{g_1}{E^2}(A^0 \cdot P_L - E) + r\,. \tag{3.35}$$

Econometric estimation is based on a system comprising (3.28), (3.19), (3.20), (3.21), (3.24), (3.33), (3.28), (3.29), and (3.34).

CHAPTER IV

ECONOMETRIC ESTIMATION

4.1 Estimation Method

In the estimation of the system described in Chapter III, we leave out equations (3.31) and (3.29) because we do not have on-farm family labor demand data and year-to-year adjustment in consumption data. However, these two variables do not appear in the other equations and also all the parameters in (3.31) and (3.29) can be estimated by the remaining equations.

Even though the estimating equation system is linear in parameters, some cross equation restrictions are nonlinear. This calls for a nonlinear estimation method. Identification of nonlinear systems of equations subject to nonlinear restrictions has been investigated by Rothenberg (1971). He finds that a system of equations is locally identifiable if the rank of the information matrix augmented with the Jacobian matrix of the constraints (evaluated at the parameter estimates) is equal to the number of unknown parameters. TSP 4.1 (Hall, Scnake, and Cummins, 1987) used in this study, checks this condition numerically at each iteration in its nonlinear system estimation techniques.

The exclusion of two equations from the system makes the covariance matrix of the system singular and since full information maximum likelihood (FIML) acts on the whole system, this eliminates it from consideration as an estimation method. Another reason for not considering FIML is that it requires that the error terms in all the equations be normally distributed; a much stronger assumption.

For estimation, we apply the nonlinear three stage least squares estimation (N3SLS) developed by Amemiya (1977) and implemented in TSP 4.1 (Hall, Scnake, and Cummings, 1987). N3SLS overcomes the weakness in FIML mentioned above in that we can get consistent estimates of the parameters in less fully specified models and there is no requirement that errors be normally distributed. An added advantage is that N3SLS is less burdensome on the computer than is FIML.

4.2 Consistency Tests

To be economically useful, the estimates of the technology part of our model must satisfy the properties of a dual profit function discussed in Chapter III. Flexible functional forms do not automatically fullfill these restrictions. The normalized quadratic profit function used in this study does impose homogeneity with respect to prices and symmetry of the Hessian. However, monotonicity and convexity must be checked statistically and imposed when necessary.

4.3 Monotonicity

Monotonicity was checked for after parameter estimation. This was accomplished through simulating predicted input quantities demanded and output supplied at each observation point. If all simulated values are positive then monotonicity is satisfied, otherwise one has to make a judgment on whether the number of violations constitutes a serious problem.

4.4 Convexity Test

One of the advantages of the normalized quadratic profit function is realized in testing for and imposing convexity. As we mentioned in Chapter III, this functional form has a constant Hessian matrix with respect to prices. The profit function is convex if the Hessian —a matrix of a_{ij} coefficients— is positive semi-definite.

One of the most popular ways to test for the positive semi-definiteness of $[a_{ij}]$ (Talpaz, Alexander, Shumway, 1989) is to reparametrize elements of the Hessian using the Cholesky decomposition, re-estimate the model with curvature restricted and test whether the curvature restricted model is statistically significantly different from the unrestricted model. As we will see below, this requires a great deal of computation.

Lau (1978) shows that any symmetric matrix A can be represented by the Cholesky decomposition, $A = LDL'$ where L is a unit lower triangular matrix (see Appendix A) and D is a diagonal matrix. The desirable property in this factorization is that if all elements of matrix D are positive then the Hessian is positive semi-definite. If some elements are negative then one can test whether they are significantly negative. The approach by Talpaz et al (1989) is to restrict elements of D to be positive by replacing D_i by D_i^2, estimate the model, and then test the restricted model against the unrestricted model using a likelihood ratio test. As expressions in Appendix II indicate, the Cholesky decomposition by itself gives rise to a model highly nonlinear in parameters. If one goes further, and squares the D_i elements, this would make it more nonlinear. The advantage of this method however, is that if convexity fails one would simply use the restricted model where convexity has already been imposed on the estimates.

Another approach described by Morey (1986) is to estimate the unrestricted, but Cholesky reparametrized, system and then test the significance of the D_i estimates using Bonferroni t statistics. This has the advantage over the Talpaz-Alexander-Shumway method in that the estimation is less nonlinear. If the test fails, one can proceed and estimate the restricted model. This method also has difficulties in converging using gradient type algorithms, as we have experienced in the course of the present study.

An approach adopted in this study, is to derive both the estimates and covariance matrix of D_i's from estimates of a_{ij}'s (see Lau, 1978b). If one can express each D_i explicitly as a function of the estimated a_{ij}'s, say,

$$D_i = D_i(A) = f_i\ (Vec(A))\ , \tag{4.1}$$

where VEC(•) is the vectorization operator, then the large sample variance of D_i can be approximated using the delta method as:

$$Var(D_i) = \left(\frac{\partial f_i}{\partial (Vec(A))}\right)' Var(Vec(A)) \left(\frac{\partial f_i}{\partial Vec(A)}\right) \tag{4.2}$$

where

$$\left(\frac{\partial f_i}{\partial (Vec(A))}\right)' = \left[\frac{\partial f_i}{\partial a_{11}}, \frac{\partial f_i}{\partial a_{12}}, \ldots, \frac{\partial f_i}{\partial a_{1k}}, \frac{\partial f_i}{\partial a_{2k}}, \cdots, \frac{\partial f_i}{\partial a_{kk}}\right].$$

From the variance of D_i and estimates of D_i, we can deduce asymptotic t-values associated with each D_i (Kmenta 1986, p.486).

Explicit expressions for D_i as functions of the elements of the Hessian matrix for a system of three input demand functions is developed in Appendix II. Using TSP 4.1, one can easily get asymptotic t-values by specifying the functions $D_i = D_i(\text{Vec(A)})$ as nonlinear restrictions and invoking the ANALYZ command. This command yields an estimate of D_i, its t-value, and the Chi-square statistic for the hypothesis that all the D_i's are simultaneously equal to zero.

The null hypothesis that the Hessian is convex in prices is equivalent to the hypothesis Ho: $D_i \geq 0$ vs Ha: $D_i \ngeq 0$ for all i simultaneously. In such a situation the Bonferroni t-test is appropriate (Morey 1986, p. 221). Under the Bonferroni t-test, the null hypothesis $D_i \geq 0$, all i = 1,k, is rejected at <u>at least</u> the $\propto$ level of significance if

$$\hat{D}_i < t_{\frac{\propto}{k}} (\infty) \, [Var(\hat{D}_i)] \tag{4.3}$$

for at least one i.

4.5 Hypothesis Tests on the Model

Our ultimate objective in this study is to investigate the differential effects of exogenous variables, government or market determined, on the growth of different-sized farms. Thus we must ascertain whether there are any differences in parameter estimates between the different size classes. If there are, we ask further where the differences emanate. From the model structure, likely sources of difference are in utility, cost of capital, and in technology parameters.

To test each of the four hypotheses above, the study adopts the Wald test as implemented in TSP 4.1. The main advantage with using the Wald test is that it only requires that we estimate the unrestricted model.

To implement these tests, however, we have to modify the estimation. Notice that the general form of our hypothesis is:

$$H_0\text{: } R(\hat{\beta}_s) - R(\hat{\beta}_L) = 0.$$

$$H_1\text{: } R(\hat{\beta}_s) - R(\hat{\beta}_L) \neq 0.$$

where $\hat{\beta}_s$ and $\hat{\beta}_L$ are estimates of

$$Y_s = f(X_s, \beta_s) + e_s .$$

$$(4.4)$$

$$Y_L = f(X_L, \beta_L) + e_L .$$

where subscripts S and L denote size classes "small" and "large." Thus we need to nest the two equations by adding an extra variable which takes on a value of one if a farm is "large" and zero if it is "small." The new unrestricted system is:

$$Y = f(X, \alpha\beta_s) + f(X, (1 - \alpha)\beta_L) + e. \qquad (4.5)$$

The new hypothesis can be written as:

$$H_0\text{: } R(\hat{\beta}) - b = 0 \qquad H_1\text{: } R(\hat{\beta}) - \beta = 0$$

where $\hat{\beta}$ is a stacked vector consisting of a vector of parameters for the small farmers and a vector for the large farmers and R(·) picks out the relevant set of parameters to be tested. That is, R(·) can pick out utility, cost of capital, or technology depending on what hypothesis we are interested in.

The Wald test as described in Green (1990, p. 129) is that, for the general hypothesis test above, we can deduce a statistic

$$W = (R(\hat{\beta}) - b)' \, (Var[R(\hat{\beta}) - b])(R(\hat{\beta}) - b) \tag{4.6}$$

having, under H_0, a Chi-square distribution with degrees of freedom equal to the number of restrictions (i.e., the number of utility, cost of capital, or technology parameters).

CHAPTER V

DATA

This chapter discusses the data set used in the econometric estimations of Chapter VI, its problems, sources, and manipulations.

5.1 The Kansas Farm Management Association Data

The farm level data used in this study comes from the records of the Kansas Farm Management Association records managed by Larry Langemeier of Kansas State University (K.S.U.). The data bank contains 483 variables per farm for 2,300 to 3,000 farms on an annual basis from 1973 through 1990 (see Langemeier, 1986).

The farms providing data are enrolled on a voluntary basis in the Kansas Farm Management Association program. In exchange, member farmers periodically get a business and enterprise analysis showing where they stand as compared to other member farmers.

The voluntary nature of program participation means that the 2,300 to 3,000 farms may not be a random sample of all farms in Kansas and this might be a problem when one tries to generalize the results of this study to the whole state. Also, there is the possibility that farmers may participate in some years and not participate in others. This creates an unbalanced set of farms; we do not have complete cross-section-time series data set. Also, as we will see below, when we sort for "wheat farms" this problem is made more acute.

5.2 Defining Wheat Farms

To avoid the problem of incorporating more than one program crop in a joint production technology, the study applies the model development in the preceding chapters on a predominantly wheat farm data set. The Kansas Farm Management Association enrolls types of farms, which necessitates that we sort for farmers who predominantly grow wheat. In the mid-western states, however, it is very rare to observe a farm which engages in wheat monoculture (Langemeier). Usually, farms have some livestock which they bring in to feed on wheat stocks after harvest, and to utilize wasteland. The objective, therefore, is to select a data set in which wheat is obviously the main farm enterprise.

The criteria which satisfy the above concerns, and in addition give us a reasonably large sample of farms to work with, are the following:

(1) Ratio of total acres planted to all crops other than wheat and , to total acres under wheat, is less than five percent.

(2) Ratio of pasture land to total operated acres is less than 50 percent.

(3) Ratio of hay acres planted to acres under wheat is less than 25 percent.

Using the above criteria we obtain a sample of 162 observations.

5.3 Size Classification

In this study we are interested in the differential effects of exogenous variables on growth among farm size classes. There are a number of ways farms can be classified. One can use total operated acres, total owned areas, or total operated crop acres. As has been mentioned before, the problem in a state such as Kansas is that a farm usually has a large expanse of low value pasture and wasteland which do not contribute to wheat production. Basing our classification on total operated acres would include such land, in turn distorting our view of wheat farm sizes. It would not seem proper, for instance, to put under one class a farm with a thousand acres of pastureland and another with a thousand acres of prime wheat cropland. Using total owned land also has the same problem, with the additional problem that such a basis would exclude an all tenant farms from classification. One would expect similar sized farms—tenant or sole proprietor—to have almost similar management decisions. For these reasons, I adopt total operated crop area as the basis for size classification in my study.

In classifying farms into distinct size classes, it is implicitly assumed that farmers in each size class share similar characteristics with respect to technology and preferences even though they might differ in terms of endowments of net equity. It also seems reasonable to expect farms with similar characteristics to be bunched together when we draw a histogram of farm sizes. The histogram of total crop area does exhibit such bunching (see Figure 5) which this study exploits in size classification. By isolating the clusters in Figure 5, we come up with the following three size classes and the number of farms in each

(a) 0 - 700 acres : 60 farms

(b) 700 - 1,089 acres : 80 farms

(c) 1,089+ acres : 22 farms.

However, the number of farms in the third class does not allow us enough degrees of freedom to estimate the model postulated in the preceding chapter. For this reason classes (b) and (c) are merged to form a class which can be referred to as "large" farms, with class (a) constituting "small" farms.

5.4 Farm Variable Input Selection

Because of degrees of freedom problems and the possible multicollinearity that can arise using flexible functional forms, a relatively small input variable set has to be specified. This necessitates having to aggregate some sets of inputs. Which inputs are aggregated and which are singly featured in the model should depend on what percentage each input occupies in the

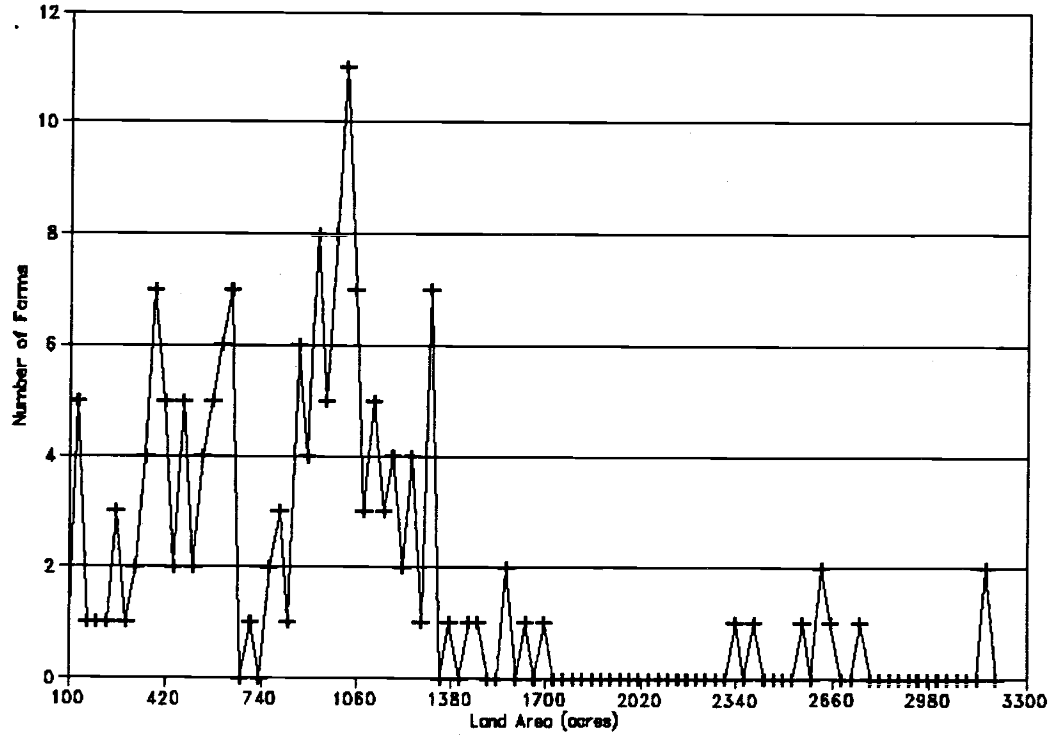

Figure 5.1. Size Distribution of Wheat Farms in the K.S.U Data Bank.

Table 5.1 . Input Costs Per Acre for Wheat in the U.S.

Inputs	Annual Average Cost per Acre ($)		Share of Variable cash costs (%)	
	1975-81	1982-85	1975-81	1972-85
Seed	5.56	6.38	16.0	12.2
Fertilizer and Lime	11.56	17.71	33.8	33.8
Chemicals	1.78	3.09	5.1	5.9
Machinery	23.48	33.86	67.6	64.6

SOURCE: U.S.D.A, ERS Information Bulletin Number 534.

total farm cost. Inputs not costly to the farm are aggregated while the major contributors to cost are featured. Table 5.1 shows contributions different inputs have on total wheat production costs.

Table 5.1 shows clearly that machine-related costs and fertilizer have been the major contributors to farm operating costs on wheat farms, combining to equal over 60 percent of expenditure. For this reason the study features machine use and fertilizer as single inputs and aggregates the other inputs into a composite variable (OTHERQ).

5.5 Data Used

In this section, we take in turn each variable used in the estimation and describe its component parts and their sources. A full set of the data used is reported in Appendix III.

Output

Wheat output (QUANT) is the sum of production from owned dryland and irrigated areas, and rented dryland and irrigated areas, reported in Kansas State University's data bank. Its price P is the average price received by Kansas farmers reported in Annual Crop Summaries (NASS).

Inputs

Fertilizer (FERTD)

The fertilizer variable is a weighted quantity index of nitrogenous, phosphorus, potassium, and lime fertilizer. The weights are formulated from annual fertilizer surveys for wheat farms in Kansas, which give average application rates and sample areas receiving each type of fertilizer. These surveys are reported periodically in Economic Research Services, United States Department of Agriculture, *Situation and Outlook Report: Resources*. Thus, for fertilizer type i the weight would be:

$$Weight = (Rate_i * Area_i) \,/\, \Sigma \, (Rate_i \cdot Area_i).$$

FERTD is generated by first finding a weighted fertilizer price index (FERTP) from individual fertilizer prices (source: Annual Crop Summaries) and then dividing the result into the total fertilizer expenditure for K.S.U. data. Dividing FERTP by the consumer price index (source: Economic Report of the President) gives us W_1, the deflated fertilizer price index.

Machinery (MECHQ)

Machine demand is deduced by dividing total cost of machine use, which includes machine hire and repair cost (source: K.S.U. data), by a national index of cost of self-propelled machinery and tractors reported by NASS. Dividing the index by CPIU gives W_2, the deflated machine price index.

<u>**Other Inputs**</u>

The rest of the other inputs (OTHERQ) are aggregated together into one quantity index. This is done by aggregating their prices and then dividing the total expenditure on these inputs by the resultant aggregate price index. Inputs comprising this aggregate are seeds, hired labor, energy, and agricultural chemicals. The seed price is national price of winter wheat seeds, since Kansas farmers grow predominantly winter wheat (source: Annual Price Summaries, NASS). The wage for hired farm workers is the per hour average earnings of farm workers in Kansas (source: Agricultural Statistics, NASS). The per gallon bulk delivered diesel price for Kansas state is used as a proxy index of energy price (source: Annual Price Summaries, NASS).

Agricultural chemicals price is a weighted average of prices of a fungicide, pesticide, and a herbicide. Based on a survey by Suguiyama and Carlson (ERS Bulletin 487, 1985) the most popular chemicals used in wheat production are the fungicide Captan-malathion-metoxychlor, the pesticide Parathion, and the herbicide 2,4-D (see Table 38). Prices of these chemicals are reported in the Annual Price Summaries. The weights for the agri-chemical price index is based on the survey by Duffy and Hawthorn (1983) who found that in their sample of wheat farmers 42 percent used herbicides, 3 percent used insecticides (i.e., pesticides), and one percent used fungicides.

The four input prices above are aggregated by performing an expenditure weighted average. The expenditures of each input are reported on a per farm basis on the K.S.U. data bank.

Fixed

Some cost items in the K.S.U. data which do not vary with production level were aggregated into a variable FIXED, which was appended to the income function (equation (3.34)). These include organization fees, crop storage and marketing, real estate taxes, personal property taxes, general farm insurance, telephone and electricity, auto expense, expense inventory change, and depreciation.

Owned and Rented Land

The K.S.U. data series reports total owned and rented cropland and also reports areas of each planted to wheat. This study focuses on the wheat enterprise and since our sorting for wheat farms still leaves us with some farmland going to alternative enterprises, the total cropland cannot be taken as the base wheat acreage, especially for program participants. To deduce whether or not a farmer participates in farm programs, we look to see whether the farm received any program payments and also whether the difference between planted area and total cropland is within the set aside requirements for that particular year. Once it is determined that the farmer is a participant, his base acreage can be approximated by inflating the planted acreage by the set aside requirement. For program non-participants, the reported planted acreates are taken to be base acreages, AREAO and AREAR.

The purchase price (P_L) of land is approximated by average value of cropland in Kansas reported by Jones and Hexem (ERS statistical Bulletin Number 813). Cropland rental rate (q_0) is approximated by multiplying the value of rented land for each farm reported in K.S.U. data bank, by the rent to value ratio reported Jones and Hexem for Kansas state. In situations where the farmer does not rent in any land, the state average rental rate reported in Jones and Hexem is taken as the rental rate.

Farm Program Variables

The source of all farm program instrument values utilized in this study, except conservation cost, is the U.S.D.A.'s Information Bulletin Number 602, which lists the various farm program instrument settings from 1960 through 1990. The variables utilized are target prices (P^T), loan rate or support price(P^S), paid required diversion rate (S1%), paid required diversion payment per bushel (S1P), voluntary diversion rate (V%), voluntary diversion payment (VP), unpaid required diversion rate (S2%), and program yield (YLD). Since no program yields were reported for each of the sample farmers, the study assumes a constant across farm program yield. Conservation cost per required diversion acre (CONSV) are calculated from total conservation cost per farm and the total idled land per farm. Per farm conservation costs are reported in the K.S.U. data bank.

Interest Payments and Net Equity

Total interest paid by the farmer is reported the K.S.U. data bank. For farms reporting a net debt at the end of the year, the effective interest rate (r) is calculated by dividing interest paid by ending debt, a total of intermediate, short-term and long-term loans. However, there are situations where the farm does not have beginning or ending debt but reports interest charges. This indicates that the farm took up and paid off short term loans during the farming year. In these situations the average Federal Land Loan interest rate (source: Financial Situation and Outlook Reports, U.S.D.A) was used to represent r.

Net equity (Et) is the ending difference between the value of farm assets and total debt reported in K.S.U. data bank. The difference between Et and beginning net equity (Et-1) gives us the net investment for the farming year.

Income and Consumption

Total income received by the farmer comes from three different sources: wheat enterprise profit (on-farm income), off-farm employment earnings, and non-wheat and non-wage off-farm income.

The wheat enterprise income is gross revenue from wheat plus farm program payments less calculated costs of inputs and fixed costs discussed above, and interest charges. Off-farm wage earnings are also reported in K.S.U. data. This, together with off-farm wage, is used to calculate off-farm labor (OFFLAB) supply. The non supervisory manufacturing wage rate for Kansas state (Source: Predicast's Source Book) is used as a proxy for off-farm payment rate (Wo). Income from other insignificant enterprises is summed together with rent from off-farm property, dividend payments from outside investments, and interest gains to form variable Y1, income from non-wheat, non-wage income.

The K.S.U. data bank also reports farmers' consumption Ct. Unfortunately, since we have an unbalanced cross-section-time series data set, we cannot deduce for all farms the change in consumption for each year. Leaving out the equation which contains the change in consumption still leaves the overall system of equations identified. The loss we have is in efficiency of estimation.

Total Available Time

Off-farm labor supply is total available time less on-farm labor less leisure time. A farm is usually not owned by a single person. There could be more than one operator owning a farm. The operator could be married and/or have children of working age. Thus, time available is variable among farms. To get around this problem, the study assumes total time available for allocation to work or leisure activities is a linear function of the product of the number of operators and the sizes of their households. This is the variable referred to as HHOLD.

CHAPTER VI

ECONOMETRIC RESULTS

The present chapter presents and discusses estimates of the econometric model described in chapters III and IV. It begins with a discussion of the econometric results of the model estimated using the entire sample of farms, small farms and large farms. This is followed by a presentation of hypothesis tests designed to determine if small and large farms are statistically distinguishable, and to validate the estimation results. The remainder of the chapter is devoted to a comparative discussion of exogenous variables effects on endogenous variables of large and small size farm models.

Results of econometric estimates are presented in Tables 6.1 to 6.3. Model validation tests are presented in Tables 6.4 and 6.5 while Table 6.6 gives estimated statistics on parameter equality hypotheses. All the tables are presented at the end of this chapter.

6.1 Overall Model Fits

All three models fit the data remarkably well. Out of 38 estimated parameters, the model with all farms included has 15 estimates significantly different from zero at the 0.05 significance level and 18 estimates significantly different from zero at the .10 significance level. The fit improves when large farm and small farm size classes are estimated separately, with 55 and 61 percent of the estimates being significantly different from zero at the 0.05 level, respectively. At the 0.10 level these numbers improve to 61 and 63 percent for large and small farms, respectively.

Each of the systems estimated yields information on input demands, effective interest rate, and farmers' utility functions. The reasonableness of the estimated parameters can be judged by how the estimates reflect their hypothesized signs.

For input demands the critical parameters are the intercepts ($-a_i$) and the slope ($-a_{ii}$) parameters. One would expect the intercept to be positive and the slope of an input demand to be negative. That is, we would expect to get downward sloping input demands.

In models estimated using data for all farms and large farms, all input demands, with the exception of on-farm labor (estimated through off-farm labor supply), show significant (at both 0.1 and 0.05 levels) hypothesized slopes and intercepts. On-farm labor demand slopes and intercepts have wrong signs, but the estimates are not statistically significant. In the small farm category, only the slope of the machinery service demand has the wrong sign which, however, is insignificant statistically.

From the discussion in Chapter II, the interest rate function should have positive parameters. All models yielded positive signs. However, g_1 is not significantly different from zero at the 0.05 level in models for all farms and large farms. For large farms g_1 is only significant at the 0.10 level.

The theoretical development in Chapter II assumes utility is concave in consumption and leisure. This requires that parameter "b1" ($(1-\alpha)/\alpha$ in equation (3.33)) be positive and less than one. In all models, b1 is significantly (at the 0.05 level) less than zero, but greater than -1. Thus, even though the sign on b1 violates the above requirement, the estimated models still satisfies the second order condition of the dynamic optimization (i.e. $(W_0L_{2C} - 1) < 0$). Also, estimating the models with b1 restricted to the positive range does not change the overall results substantially. For this reason, the unrestricted results are utilized in all subsequent analyses.

6.2 Testing Profit-Maximizing Price-Taking Behavior

In the theoretical development of the model, I presume that each farmer behaves as a price-taker; maximizing profit subject to a continuous concave twice differentiable production function. This assumption is now subjected to empirical examination. As the discussion in Chapter III points out, if farmers behave according to the above postulate, then the profit function should satisfy the properties: (a) homogeneity of degree 1 of profit in prices, and homogeneity of degree 0 of output supply and input demands in prices; (b) symmetry of cross-partial derivatives of the profit function with respect to prices; (c) convexity of the Hessian matrix, and (d) the monotonicity of supply and input demands in output and input prices, respectively.

As pointed out in Chapter IV, the normalized quadratic profit function utilized in this study imposes the homogeneity and symmetry conditions, but does not restrict convexity or monotonicity. Monotonicity is checked for each model for each observation. A summary of violations and the average percentage of observations in violation, for each endogenous variable -quantity or input demand- is given in Table 6.4 for each model. The table shows very few violations of monotonicity, with percentage violations being 0.6 percent for all farms, 2.6 percent for small farms and only 0.9 percent for large farms.

Convexity test results as described in Chapter IV are given in Table 6.5. The Bonferroni t-test on whether any of the D_{ii} are significantly less than zero fail to reject the hypothesis that the Hessian is positive semi-definite for all three model estimations. Thus, we cannot reject the hypothesis that the profit function is convex in input prices.

6.3 Tests on Equality of Parameters Between Small and Large Farms

Before we go further in the analysis of differential growth effects of exogenous variables on small and large farms, we have to empirically test whether or not there is any statistical difference between the parameters of the two models. If there is, it would also be beneficial to know which parts of the models differ. Tests on such comparisons were described in chapter IV, the results of which are presented in Table 6.6.

In the case of all parameters taken as a whole, the Wald test rejects the null hypothesis that the parameters of small and large farm models are the same. This supports the results of Henneberry, Tweeten, and Nainggolan (1991). It is important in that, we can now legitimately discuss differential effects in different size classes.

Performing the Wald test on equality of technology parameters shows that (at $\alpha = 0.05$ or $\alpha = 0.10$) there is no statistical support for equality of technology (i.e. profit function) parameters across size classes. However, we fail to reject the hypothesis that cost of capital parameters are different between large and small farms. That is, statistically there is no bias in bank lending policies toward either small or large farms with comparable net equity positions. At both significance levels 0.10 and 0.05 a t-test on the difference between the utility parameter in large and small farms rejects the hypothesis of equality. This is probably due to differences in farmer ages between the different size classes.

6.4 Comparative Shortrun Effects of Exogenous Variables on Endogenous Variables

Here we contrast the short run effects of exogenous variables on small and large farms. The importance of this is that it may help explain differential dynamic effects of these exogenous variables on growth. To help contrast technology differences, input demand elasticities evaluated at the means are presented in Table 6.7 and 6.8. Cost of capital and utility effects are contrasted separately.

6.4.1 Program Adjusted Owned Land Use Price ($\bar{r}$)

In both small and large farms, an increase in $\bar{r}$, defined in Chapter II as the program adjusted owned land price, leads to a statistically significant decrease in owned land demand as expected. In percentage terms, the magnitude of the decrease in large farms is twice that on small farms. On rented land, $\bar{r}$ leads to a statistically significant increase in rented area demanded, which implies that rented and owned land are substitutes in production. Once again the effect on large farms is more than on small farms, implying greater substitutability between owned and rented land in this size class. This helps explain the differences in own price effects.

The effect of $\bar{r}$ on off farm labor supply is positive on both large and small farms, although the magnitudes of the effects are not dramatically different. Moreover, the effect is not statistically significant on large farms. The positive effect on supply implies a negative effect on on-farm labor demand, which further implies that family labor is complementary to owned land. This makes intuitive sense since family labor is usually required for supervision.

The effect of $\bar{r}$ on fertilizer is surprising. On both small and large farms, an increase in $\bar{r}$ leads to statistically significant decreases in fertilizer demanded, implying owned land and fertilizer are complements. Intuition tends to support the alternative that, since fertilizer is a land saving input, it should be a substitute for owned land. In terms of magnitudes, the effect on small farm fertilizer demand is more than five times that on large farms.

Regarding machinery service demand, $\bar{r}$ has a positive effect on small farms and a negative but statistically insignificant effect on large farms. In the case of "other input" (OTHERQ) demand, $\bar{r}$ has a positive but statistically insignificant effect in small farms and a positive significant effect in large farms. Thus, owned land is a substitute in production to both machinery and OTHERQ. In the case of machinery demand this result runs counter to the conventional wisdom which says that land and machinery should be complements. The negative but insignificant effect in large farms is more in keeping with the conventional wisdom. One way to explain this is that scales of operation within the small farm size class do not allow economies of scale to be realized.

6.4.2 Land Rental Rate (q_0)

In small farms the effective land rental rate only has a statistically significant effect on owned and rented land demands, with the effect on rented land being negative and on owned land positive. Large farms are also affected similarly with larger statistically significant effects than small farms. This reinforces the strong rented-owned land substitutability in large farms discussed above.

In addition to effects on owned and rented land demands, rental rate has statistically significant positive effects on fertilizer and machinery demands and insignificant effects on the other inputs in large farms. This suggests that in large farms rented land is a substitute for both fertilizer and machinery services.

6.4.3 Off-farm Wage Rate (W_0)

In large farms, off-farm wage (W_0) does not have any statistically significant effect on any input, whilst in small farms Wo has large significant effects on off-farm labor supply - hence on-farm labor demand - on fertilizer, and on machinery service demands. This reflects the findings of Smith, Richardson, and Knutson (1985) suggesting that off-farm income is important to small farms and less important to large farmers. The results on small farms imply that on-farm labor is complementary to fertilizer and substitute to machinery in production. Also, worth noting is the absence of a significant effect of W_0 on land demand.

6.4.4 Fertilizer Price (W_1)

In both small and large farms, fertilizer price has a negative significant effect on owned land demanded, reflecting the complementarity between owned land and fertilizer alluded to earlier. The effect is larger in small than in large size classes. In the case of rented land, fertilizer price does not have a significant effect on small farms, but has a positive significant effect on large farms, suggesting that in large farms fertilizer and rented land are substitutes.

In large farms, fertilizer price does not have a significant effect on off-farm labor supply whilst in small farms it has a positive effect. This implies that W_1 has a negative effect on on-farm labor demand. The own price elasticity of demand for fertilizer is negative in both large and small farms, with the effect greater in small than in large farms. Though both machinery and OTHERQ demands are positively affected by fertilizer price, the effect on machinery in large farms, and the effect on OTHERQ in small farms, are insignificant statistically.

6.4.5 Machinery Service Price (W_2)

Machinery price has significant effects on small farm demands for all inputs except rented land. In the case of large farms, it has significant effects only on the demands for rented land, machinery, and OTHERQ. The own price demand effects are negative for both models, with the effects greater in small than in large farms. On OTHERQ, the other input in which both size classes show significant results, machinery price has a greater effect in small than in large farms. Overall the effects imply that machinery services are complementary to on-farm labor but substitute to owned land, rented land, fertilizer and OTHERQ in production.

6.4.6 Other Inputs Price Index (W_3)

The "other inputs" price index W_3 has significant own and cross effects with machinery services in small farms. In large farms, in addition to own and machinery demand effects, it also has statistically significant effects on demands for owned land and fertilizer. The effect on fertilizer demand is positive and roughly the same magnitude in both small and large farms. This again supports the argument that machinery and OTHERQ are substitutes. The own price demand effect is negative and larger in small than in large farms. In large farms the effects on fertilizer and owned land indicate that OTHERQ is net substitute to each of the two inputs.

6.4.7 Other Parameter Comparisons

Statistical tests on parameter equality between small and large farms discussed earlier in this chapter show there are no statistical differences between cost of capital parameters. They show however, that the utility parameter in the two models differ. From Chapter II the utility parameter is in effect the marginal rate of substitution between off-farm-wage-valued leisure time and money value of consumption. The results (see Tables 6.2 and 6.3) show that the absolute value of this rate in large farms is greater than in small farms, implying that large farmers are willing to give up a larger proportion of consumption to gain a unit of leisure than are small farmers. This makes intuitive sense since larger farmers are usually wealthier and thus tend to value leisure more.

Table 6.1 .Estimated Parameters : All Farms.

	Coeficient	Value	Asymptotic t-ratio	R^2
Off-farm labor	ac	21722.2	14.1869 **	0.51
	at	512.674	3.2769 **	
	a0	294.369	0.5930	
	a00	1035.46	1.4954	
	a01	6.7417	1.4965	
	a02	-70.926	-1.9256 *	
	a03	-117.996	-1.3555	
	ar0	-8.6827	-0.7079	
	aq0	-2.9646	-0.2529	
	at0	46.578	1.7758 *	
	b0	-49.64	-0.6960	
	b1	-0.41292	-10.037 **	
Interest	g0	0.10198	20.685 **	0.016
	g1	208.525	1.5479	
Other Inputs	a3	-2869.48	-4.8514 **	0.009
	a33	569.229	2.8732 **	
	ar3	-51.5997	-3.0270 **	
	aq3	-3.83054	-0.1782	
	at3	71.4814	0.6431	
Machinery	a2	-66.7327	-2.7142 **	0.042
	a22	4.70776	2.4677 **	
	a23	-16.5452	-2.7755 **	
	ar2	-0.25225	-0.3247	
	aq2	-1.27251	-1.5473	
	at2	-6.94535	-0.6356	
Fertilizer	a1	-47.7213	-8.5251 **	0.029
	a11	0.17711	2.4682 **	
	a12	-0.3537	-1.5912	
	a13	-3.7023	-2.6270 **	
	ar1	0.60537	4.1524 **	
	aq1	-0.0907	-0.4857	
	at1	-0.31794	-0.07364	

(CONTINUED next page)

Table 6.1 Continued. Estimated Parameters : All Farms.

	Coeficient	Value	Asymptotic t-ratio [a]	R^2
Owned Land	ar	-197.104	-4.12196 **	0.032
	arr	2.1629	1.3140	
	aqr	-7.7129	-3.5294 **	
	atr	-5.9502	-1.3689	
Rented Land	aq	-414.717	-5.7864 **	0.032
	aqq	15.034	5.0137 **	
	atq	-6.4861	-1.0802	

a. Critical t-values are 1.65 at the 0.10 level and 1.98 at the 0.05 level of significance. Single asterisks indicate significance at the 0.10 level, while double asterisks indicate significance at the 0.05 level.

Table 6.2 . Estimated Parameters : Large Farms.

	Coeficient	Value	Asymptotic [a] t-ratio	R^2
Off-farm Labor	ac	26673.8	14.756 **	0.59
	at	928.928	4.277 **	
	a0	232.214	0.341	
	a00	658.444	0.6178	
	a01	9.862	1.577	
	a02	-70.185	-1.329	
	a03	163.974	-1.124	
	ar0	-16.4014	-0.8092	
	aq0	8.689	0.3374	
	at0	73.976	1.9631 *	
	b0	17.095	0.1525	
	b1	-0.4284	-8.3190 **	
Interest	g0	0.1009	24.844 **	0.058
	g1	196.359	1.946 *	
Fertilizer	a1	-49.849	-6.588 **	0.065
	a11	0.20998	2.1821 **	
	a12	-0.4395	-1.4694	
	a13	-5.8506	-2.524 **	
	ar1	0.5538	2.375 **	
	aq1	-0.8988	-2.3023 **	
	at1	8.5503	1.4454	
Machinery	a2	-107.393	-2.9961 **	0.096
	a22	5.2028	2.049 **	
	a23	-22.6095	-2.0733 **	
	ar2	1.3405	1.0534	
	aq2	-3.1038	-1.7305 *	
	at2	-25.981	1.6153	
Other Inputs	a3	-4127.64	-5.2730 **	0.009
	a33	760.485	2.4378 **	
	ar3	-96.7602	-3.4278 **	
	aq3	41.8527	1.0664	
	at3	-41.5495	-0.2657	

(CONTINUED next page)

Table 6.2 Continued. Estimated Parameters: Large Farms.

	Coeficient	Value	Asymptotic [a] t-ratio	R^2
Owned Land	ar	-196.536	-2.6569 **	0.18
	arr	11.3434	2.9612 **	
	aqr	-18.3405	-4.6416 **	
	atr	-17.1269	-2.4970 **	
Rented Land	aq	-584.249	-5.6198 **	0.05
	aqq	30.4962	3.7808 **	
	atq	-2.2298	-0.2375	

a. Critical t-values are 1.661 at the 0.10 level and 1.985 at the 0.05 level of significance. Single and double asterisks indicate, respectively, significance at the 0.10 and 0.05 levels.

Table 6.3 . Estimated Parameters: Small Farms.

	Coeficient	Value	Asymptotic[a] t-ratio	R^2
Off-farm Labor	ac	13384.1	11.02 **	0.13
	at	192.14	1.401	
	a0	-1403.28	-2.746 **	
	a00	1047.86	2.228 **	
	a01	10.245	-2.447 **	
	a02	-82.725	-3.254 **	
	a03	83.939	0.942	
	ar0	7.862	1.105	
	aq0	-11.367	-1.124	
	at0	107.228	3.901 **	
	b0	187.801	2.504 **	
	b1	-0.2911	-3.597 **	
Interest	g0	0.068	6.277 **	0.005
	g1	5954.84	6.850 **	
Fertilizer	a1	-46.578	-6.360 **	0.023
	a11	0.1839	1.983 *	
	a12	-0.6534	-2.729 **	
	a13	-0.1446	-0.106	
	ar1	1.1653	12.369 **	
	aq1	0.1427	0.9780	
	at1	1.8527	0.5253	
Machinery	a2	1.2287	0.0610	0.059
	a22	5.5510	3.9330 **	
	a23	-7.4943	-2.0840 **	
	ar2	-1.8447	-5.6140 **	
	aq2	-0.0408	-0.0915	
	at2	-12.298	-1.5420	
Other Inputs	a3	-2189.89	-6.7696 **	0.096
	a33	412.785	3.6945 **	
	ar3	-4.8236	-0.5967	
	aq3	9.8934	0.9029	
	at3	51.0569	0.7520	

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Table 6.3 Continued. Estimated Parameters: Small Farms.

	Coeficient	Value	Asymptotic[a] t-ratio	R^2
Owned Land	ar arr aqr atr	-341.106 2.8595 -1.9557 4.08496	-8.669 ** 6.012 ** -2.022 ** 1.0993	0.10
Rented Land	aq aqq atq	-161.354 4.7157 -4.6405	-3.772 ** 2.958 ** -1.213	0.047

a. Critical t-values are 1.671 at 0.10 level and 2.00 at 0.05 level of significance.

Table 6.4 . Monotonicity Check on Estimated Models.

Endogenous Variable	Number of Monotonicity Violations		
	All Farms	Small Farms	Large Farms
Off-farm Labor	6	7	6
Fertilizer	0	3	0
Machinery	0	0	0
Owned Land	0	0	0
Rented Land	1	1	0
Other Inputs	0	0	0
Wheat Output	0	0	0
Average % Violations	0.645	2.62	0.90

Table 6.5 . Convexity Tests on Technology Estimates.

D	All Farms [a]		Small Farms [b]		Large Farms [c]	
	Value	t-ratio	Value	t-ratio	Value	t-ratio
D_{11}	2.1629	1.314	2.8595	6.012	11.3434	2.9612
D_{22}	-12.470	-0.540	3.3781	1.828	0.8424	0.0646
D_{33}	1092.91	1.7657	1015.62	2.1761	257.362	0.0407
D_{44}	0.3452	1.2886	-0.5869	-1.5732	-0.1653	-0.0104
D_{55}	0.6039	0.3095	3.5356	0.6338	391.529	0.0617
D_{66}	-60.501	-0.0268	387.265	3.0424	-0.3E+8	-0.0117

a. Critical Bonferroni t-statistics are -2.36 at 0.05 level and -2.00 at the 0.10 level.

b. Critical Bonferroni t-statistics are -2.39 at 0.05 level and -2.20 at the 0.10 level.

c. Critical Bonferroni t-statistics are -2.366 at 0.05 level and -2.055 at the 0.10 level.

Table 6.6 . Hypothesis Tests on Equality of Parameter Estimates Between Small and Large Farm Classes.

Parameter comparison	Test Statistic	Significance	
		$\alpha = 0.05$	$\alpha = 0.01$
All Parameters [a]	Wald = 253.96	Yes	Yes
Technology [b]	Wald = 230.55	Yes	Yes
Cost of Capital [c]	Wald = 0.5498	No	No
Utility [d]	t-value = -3.294	Yes	Yes

a. Critical Chi-square: 29.05 (at 0.10) and 26.51 (at 0.05)

b. Critical Chi-square: 25 (at .10) and 22 (at 0.05).

c. Critical Chi-square: 0.21 (at 0.10) and 0.10 (at 0.05).

d. Critical t-value: 1.645 (at 0.10) and 1.96 (at 0.05).

Table 6.7 . Input Demand Elasticities Evaluated at the Means: Large Farms.

Price Variable	Owned land	Rented Land	Off-farm Labor	Fertilizer	Machinery	Other Inputs
r	-0.339	0.331	0.287 #	-0.211	-0.126 #	0.209
q	0.4069	-0.396	0.113 #	0.255	0.216	-0.007 #
W0	0.069 #	-0.021 #	1.624 #	-0.530 #	0.926 #	-0.05 #
W1	-0.140	0.133	1.465 #	-0.680	0.350 #	0.107
W2	0.110 #	0.150	-3.384 #	0.462	-1.343	0.135
W3	0.259	-0.066 #	0.257 #	0.200	0.190	-.147

Note: # denotes insignificance at the 0.10 level.

Table 6.8 . Input Demand Elasticities Evaluated at the Means: Small Farms.

Price Variable	Owned Land	Rented Land	Off-Farm Labor	Ferti-lizer	Machine-ry	Other Inputs
r	-0.168	0.146	0.222	1.204	0.500	0.037#
q	0.103	-0.316	-0.288#	-0.132#	0.010 #	-0.068#
W0	-0.070#	0.129#	4.507	-1.611	3.438	-0.098#
W1	-0.593	-0.092#	2.503	-1.643	1.542	0.010#
W2	0.328	0.009#	7.062	2.039	-4.579	0.174
W3	9.318#	-24.22#	0.224	4.904 #	0.1934	-0.299

# indicates nonsignificance at the 0.10 level.

CHAPTER VII

EMPIRICAL GROWTH EFFECTS OF GOVERNMENT PROGRAM AND MARKET VARIABLES

The present chapter utilizes econometric results of Chapter VI to investigate effects of program and nonprogram factors on average farm growth in each of the two size classes. This is accomplished by setting to zero the changes in net equity and consumption in equations 4.28 and 4.29. The resultant equations are implicit functions of longrun net equity and consumption. Differentiating these two equations with respect to exogenous variables gives their effects on longrun net equity and consumption. From equations 3.34 and 3.35 I derived expressions for λ_1 and Z_1, the parameters of the optimal trajectories in the neighborhood of the steady-state. Evaluating the effects on the steady-state net equity and consumption, at the means of the exogenous variables for each size class, yields results of Table 7.1. Results reported in Table 7.1 are then combined with deduced parameters Z_1 and λ_1 to give local dynamic effects presented in graphs Figure 7.1 to 7.30. Table 7.2 gives the longrun effects of exogenous variables on owned and rented land.

The discussion in this chapter is presented in three sections. First, I discuss the empirical longrun effects of exogenous variables and compare them to the qualitative results of Chapter II. Second, a comparative analysis of the effects on the different size classes over time is presented and discussed. Finally, I present and discuss the net equity and direct effects of the exogenous variables on owned and rented land in the two size classes.

7.1 Comparison of Steady State Comparative Static Results

Theoretical and empirical comparative static results are given in Tables 2.2 and 7.1 respectively. Go, the paid diversion rate in Table 2.2 can be taken as the total of S1P, VP and CONSV instruments in Table 7.1. Instruments S1P and VP increase Go whilst CONSV reduces Go. If on-farm labor and land are substitutes, the theoretical model predicts Go will have a positive effect on both longrun net equity and consumption. Empirical results in both size classes confirm this result.

The program variable s, the required diversion percentage, which is reflected by instruments S1% and S2% in the empirical models, is predicted to have a positive effect on net equity if the owned land own price elasticity (σ) is less in absolute value than K_s (defined in Appendix I), and a negative effect when σ is greater than K_s in absolute value. The empirical results show that S1% and S2% both have positive effects on small farm net equity and consumption and negative effects on large farm net equity and consumption. This suggests that the owned land own price elasticity in large farms is greater than K_s while in small farms it is less than K_s. This result suggests that if government has as its objective improving the longrun financial condition of small farms then S1% and S2% are good instruments to achieve it, albeit to the detriment of large farms.

Before I go further with the current comparison it is important to point out that Table 2.2 shows that if on-farm labor is complementary to land, then consumption effects are indeterminate. In the previous chapter results showed that generally on-farm labor is complementary to land, implying that the theoretical model cannot predict the long term effects on consumption. Therefore, this leaves us with effects on net equity as the basis for judging how well the theoretical model predicts the empirical effects.

Results show that the effects of instrument V, the voluntary diversion percentage, reflected by V% in the empirical model, have similar effects on net equity and consumption as do instrument S. This suggests that owned land own price elasticity of demand is greater than K_v (as defined in Appendix I) in large farms and less than K_v in small farms.

The effects of the other program instruments, including target price, loan rate, and program yield, manifest themselves through the deficiency payment rate per acre, denoted DEFICIENCY in Table 7.1. From the discussion of the effects of each of these instruments in Chapter II, the effect of deficiency payment rate on longrun net equity is predicted to be positive. The empirically deduced effect is positive in both small and large farms as predicted.

In both the theoretical and empirical models, output price has a negative effect on net equity. This seemed counter intuitive in the theoretical discussion since consumption effect could not be readily predicted. The empirical results show output price with a very large positive effect on consumption, so that an output price increase is beneficial to the farmer.

In the theoretical discussion of Chapter II, land purchase price (P_L) was one of the variables whose effect could change depending on the absolute size of the owned land own price demand elasticity. The empirically generated effects, however, show both small and large farms' net equity being affected positively by an increase in P_L. This suggests that the own price elasticity of demand for owned land has an absolute value less than K_{PL} (defined in Appendix I). Effect of land rental rate on the other hand is predicted to be positive since owned and rented land are substitutes. The empirical results confirms that proposition.

For the rest of the variable inputs - fertilizer, machinery, on-farm labor, and other inputs - the theoretical analysis predicts that, as long as the inputs are complementary to land, then an increase in their prices should decrease longrun net equity, with the opposite being true if they are substitutes. All inputs, except fertilizer, are substitutes for owned and/or rented land. Fertilizer clearly shows complementarity with rented and owned land, suggesting, according to the theoretical discussion, its price should have a negative longrun effect on net equity. Empirical results show all input prices having positive longrun net equity effects. Thus, except in the case of fertilizer price, the empirical results do not go against our theoretical propositions.

On the whole, the empirical results follow the theoretical predictions rather well. In the next section I turn attention to differences in exogenous variable effects on net equity and consumption, and their adjustments over time, between small and large farms.

7.2 Differential Dynamic Effects of Program and Non-Program Factors on Small and Large Farm Net Equity and Consumption.

The local dynamic effects in the ϵ-neighborhood of the steady state equilibrium examplified by equations (2.54) and (2.55) in Chapter II provide a particularly attractive way to look at effects of exogenous variables over time. For instance, evaluating effects (2.54) and (2.55) at time $t = 0$ gives the immediate effect of an exogenous variable increase. Evaluating the effects as time goes to infinity recovers the longrun effects of Table 7.1 and in between, we get the medium-term effects of exogenous variables. This is made clear with use of graphs plotting, for each farm size, the evolution of the effects from $t = 0$ onwards, making comparison across size classes more dramatic. Such plots are presented in Figures 7.1 to 7.30 for each factor and for net equity and consumption effects. I now discuss these effects in turn.

7.2.1 Government Programs

The effects of a δ-increase in the paid required diversion percentage

(S1%) on net equity and consumption path over time are given in Figures 7.1 and 7.2. The two graphs show that the instant S1% is increased, consumption changes whilst net equity does not. This is because the process of investment and divestment takes time. As time goes by, S1% triggers investment in small farms whilst in large farms it leads to a reduction in net equity. From the slopes of the two curves, the rate at which these two opposing effects unfold over time is higher in large farms than in small farms. Also, in the long term the net equity gain by small farms is about three times less in percentage terms than is the loss by large farms.

What S1% induces in consumption is the opposite of what it does to net equity. It encourages substantial short run increases in consumption for large farms whilst in small farms it reduces consumption in the short run. This fits with the net equity effects since for small farms to invest they have to reduce consumption now to save money to finance those investments. For large farms to increase consumption, they probably have to borrow money, which reduces net equity. The reduction in net equity by large farms hampers their ability to generate income in the future, leading to lower longrun consumption levels. As figures 7.3 to 7.6 all show, unpaid required diversion and voluntary diversion percentages also show effects similar to S1%.

Deficiency, paid diversion, and voluntary diversion payment rates share similar effects on net equity and consumption, as Figures 7.7 to 7.12 show. Each has a positive effect on net equity, the effects being greater on small than on large farms at each stage of the adjustment period. Furthermore, the rate of change is greater on small than on large farms. The initial effect on consumption for both size classes is to reduce consumption to finance anticipated investments. The percentage reduction is higher in small farms than in large. This higher savings rate in small farms is reflected in higher longrun increases in consumption than on large farms.

In contrast to effects of payment rates, conservation costs per acre (CONSV) decrease small farm net equity accumulation more than they decrease large farm net equity accumulation (see Figure 7.13). This is understandable since an increase in CONSV increases small farm short run consumption (see Figure 7.14). As a result, small farms have a higher rate of net equity decline and consequently a lower net long run consumption than do large farms.

On the whole, the results show that farm programs have tended to improve small farm financial conditions more than they do large farms. Land retirement instruments have tended to increase small farm net equity and to decrease large farm net equity. Payment-type programs have led to net equity improvements in both large and small farms, but the percentage magnitudes and rates of impacts over time have been more in favor of small farms.

7.2.2 Output Price

As Figure 7.15 shows, an increase in wheat output price leads to a decline in net equity in both large and small farms, which might seem counter intuitive. However, to make sense, this result must be viewed together with the effect of output price on consumption. As Figure 7.16 shows, an increase in price leads to immediate increases in consumption in both size classes. The subsequent decline in consumption as net equity settles to its lower equilibrium position still leaves longrun consumption positive. What this seems to suggest is that the increases in product price afford farmers the luxury of being able to maintain or even increase their consumption with a lower resource base. The empirical results also show that large farms enjoy more of this advantage than small farms do.

7.2.3 Variable Inputs

Effects of variable inputs on net equity and consumption, as alluded to in the previous section, have not been uniform. This is understandable since the nature of the effects is dependent on their relationship to land in the production process. Results show that this relationship has varied across the inputs. Figures 7.17 to 7.24 illustrate the differential effects.

Off-farm wage rate has had a positive effect on net equity and a negative effect on consumption for both small and large farms (see Figures 7.17 and 7.18). Also the negative effect on consumption persists in the long term. One way to explain this result is that it follows from the complementarity between leisure and consumption which the theoretical models assumes, and which the empirical model imposes through a log-linear utility function. The argument would then be that an increase in off-farm wage rate would increase off-farm earnings available for investment in land. Since land is complementary to on-farm labor the increase in land would increase on-farm labor. Also, an increase in wages would increase the farmers supply of labor to off-farm work, leading to a decrease in leisure time. But leisure is complementary to consumption which implies that consumption has to decrease. The empirical results show that large farms increase investment more, and decrease consumption less, than do small farms in the whole process.

Fertilizer, machinery, other inputs, and rental prices all have uniform effects on net equity and consumption (see Figure 7.19 to 7.24 and 7.27 and 7.28). Differences among these inputs across the different size classes are in magnitudes and rates. An increase in any of the input prices induces a process of growth as farmers substitute the now expensive inputs with land. They accomplish this by sacrificing consumption in the short to medium term. For small farms this short term sacrifice in consumption is rewarded by long term increases in consumption in all except machinery price. In large farms on the other hand, only land rental rate and fertilizer price increases result in long-run increases in consumption.

Fertilizer price increase induce deep short run consumption cuts but at the same time greater net equity increases in small farms than in large. Consequently, the long term consumption improvements are higher in small farms. Machinery service price has similar effects except that the long term consumption improvement is in form of a lower loss in consumption. The price index of the composite input OTHERQ, on the other hand, has large farms sacrificing more short term consumption for faster and higher long term net equity growth. However, this higher investment is not translated into comparatively higher longrun consumption. Small farms which experience modest net equity growth end up with longrun increases in consumption.

The effect of land rental rate sets it apart from that of the other variable inputs just discussed (see Figures 7.27 and 7.28). The net equity growth effect of an increase in rent on large farms is lower or equal to that on small farms in the short to medium term, but becomes larger in the medium to long term. This is partly because the rate of change in growth rate is about constant in the case of large farms but is decreasing in small farms. The opposite is the case with effect on consumption. Here small farm consumption change over time is lower in the short term but greater in the medium to long term. However, in the short term the differences in the magnitudes of the effects are very small.

7.2.4 Land Purchase Price

The effect of an increase in the land purchase price in both large and small farms is to induce investment, reduce consumption in the short to medium run and increase both long-run equilibrium net equity and consumption. This result makes intuitive sense since increased value of land increases the attractiveness of holding land, which entails some sacrificing of consumption in the short term. Increased net equity improves future income generation, which improves longrun consumption. Empirical results indicate (see Figures 7.25 and 7.26) that small farms react to purchase price increases with relatively bigger sacrifices in short term consumption than do large farms. This is reflected in the greater long term net equity percentage growth and speed of adjustment experienced by small farms relative to large farms. The long term differences in consumption gains, however, are not very large.

7.2.5 Technical Change

Technological advances affect small and large farms similarly. They induce net equity growth with some short term consumption decreases as farms take advantage of opportunities presented by new technology. The effects are much greater in large than in small farms, lending support to the traditionally held view that technological advances lead to more growth in large farms than in small. The adjustment process though takes much longer in large farms than in small farms. Thus, small farms begin having positive changes in consumption from the technological advances much earlier than do large farms.

7.3 Comparative Effects of Exogenous Variables on Rented and Owned Land

In this section I discuss the long term effects of exogenous variables on owned and rented land. In the previous chapter, I discussed short-run effects on all inputs, including owned and rented land. The effects were short run because they assumed net equity constant. In the longrun net equity is affected by the exogenous variables as we have discussed in preceeding section. Since our major objective is to examine determinants of farm growth, I limit the discussion to the land variables.

Longrun effects an exogenous variable on land (A) can be decomposed as follows:

$$\frac{d\,A}{d\,\phi_i} = \frac{\partial A}{\partial \phi_i} + \frac{\partial A}{\partial r} \cdot r_E \cdot \frac{\partial E^*}{\partial \phi_i} \qquad (7.1)$$

where the first right hand term represent the short run effect and the second term gives the indirect effect of the exogenous variable through changes in longrun net equity. The above longrun effects evaluated at the mean of exogenous variables and the longrun net equity and consumption, are generated as percentages of longrun owned and rented land. The results for both small and large farms are give in Table 7.2. I will briefly discuss these effects in turn.

7.3.1 Program Instruments Effects

As in effects on net equity, all the set aside program instruments induce changes in the same direction. Increases in set aside instruments lead to an increase in owned land on both small and large farms, which is surprising since the comparative static results on net equity show that in larger farms, net equity is reduced. Also, the magnitudes of the increases are much higher in large farms. A way to explain this is that large farmers are more willing to go into debt to finance much larger investments than are small farms. By almost equal percentages within each size class, though, the same program instruments induce negative effects on rented land. Thus, one would expect total scale of operation not to change much, leaving the overall program effect to be a change in tenure toward more ownership and away from tenancy. The effect is more so in large than in small farms.

The payment rates instruments (deficiency, voluntary and paid diversion) have positive impacts on both rented and owned land in small farms. Thus, they induce growth in scale of production of small farms. In large farms, on the other hand, these instruments increase rented land and decrease owned land, thus tending to shift tenure toward tenancy rather than toward ownership. The conservation unit cost variable does the opposite of the payment rates instruments. It ambiguously leads to a scaling down of operations on small farms. In large farms it leads to an increase in owned land and to a decrease in rented land.

7.3.2 Prices Effects

In keeping with the net equity reducing effect reported earlier, output price decreases owned land in both large and small farms. In small farms, however, it increases rented land while in large farms it decreases rented land. Thus, in large farms output price unambiguously reduces the average scale of the farm, while the scale effect is not so clear in small farms. The percentage reduction in owned land, like in net equity, is higher in large farms than in small farms.

All the other prices have a positive effect on land holding in both large and small farms. In small farms they all have positive effects on rented land, implying that all input prices increase the scale of operation in small farms. In large farms, off-farm wage rate and the aggregate input price index have negative effects on rented land, making their effect on scale ambiguous.

The overall effect of these price variables is a move toward more ownership relative to tenancy in both large and small farms. Off-farm wage rate and the aggregate input price induce greater effects on owned land in large farms, while fertilizer and machinery price do the same in small farms. All prices affect small farm rented land more positively than in large farms. Thus, the input prices induce more of a trend toward land ownership in small than in large farms.

7.3.3 Technical Change

Technical change increases owned land and rented land in large farms and hence increases the scale of production. This supports the traditionally held view that technical change has led to increases in average farm sizes. The effect on small sized farms is ambiguous, since owned land is negatively affected while rented land is positively affected.

Table 7.1 . Empirical Growth Effects of Farm Program and Market Factors Evaluated at The Means of Exogenous Variables.

Δ Exogenous Variable	Small Farms		Large Farms	
	Net Equity (10-5)	Consumption (10-5)	Net Equity (10-5)	Consumption (10-5)
S1%	65.00	-12.82	-175.064	-124.408
S2%	18.26	-28.14	-188.394	-128.264
V%	34.29	-22.88	-184.382	-126.5133
DEFICIENCY	4.23	1.39	0.8168	0.3231
CONSV	-0.44	-0.15	-0.0754	-0.03
S1P	1.73	0.57	0.4415	0.1746
VP	2.15	0.71	0.4635	0.1833
P	-2.40	6.53	-11.558	7.922
W0	3.60	-4262	5.74	-3639.74
W1	4.46	1.66	1.5421	0.4841
W2	4.85	-0.01	1.3654	-0.7695
W3	5.24	3.26	19.7023	-0.3072
PL	4.70	1.47	1.4334	0.2684
q0	4.88	1.30	5.1744	0.9635
T	2.49	86.64	16.56	19.023
δ	0.0	-0.994	0.0	-0.0288
Local Dynamics Coeficients	λ = -0.041478 Z = 16.88615		λ = - 0.035294 Z = 20.26914	

Each cell contains the partial derivative of equilibrium net equity (consumption) with respect to an exogenous variable, divided by equilibrium net equity (consumption).

Table 7.2 . Effects of Partial Changes in Exogenous Variables on Long Run Owned and Rented Land in Percentage Terms.

Exogenous Variable	Small Farms		Large Farms	
	Owned Land	Rented Land	Owned Land	Rented Land
S1%	0.0364934	-0.027452	0.44785	-0.4571575
S2%	0.0088089	-0.0417222	0.45027	-0.4791883
V%	0.0183042	-0.0368267	0.44927	-0.4701214
Deficiency	0.0025038	0.0012906	-0.0002024	0.0018461
CONSV	-0.0002624	-0.0001353	0.0000187	-0.0001704
S1P	0.0010273	0.0005295	-0.0001094	0.0009979
VP	0.0012743	0.0006569	-0.0001148	0.0010473
P	-0.0013181	0.0061607	-0.023698	-0.013000
W0	0.0021482	0.0018053	0.010628	-0.0014088
W1	0.0026452	0.0013695	0.0012336	0.0007871
W2	0.0028714	0.0013765	0.0008194	0.0011866
W3	0.0030970	0.0010362	0.041879	-0.0071725
PL	0.0027856	0.0013568	0.00095631	0.00095033
q0	0.0028872	0.0011879	0.0093632	-0.0050032
T	-0.012333	0.0070532	0.056545	0.0036403
δ	0.0	0.0	0.0	0.0

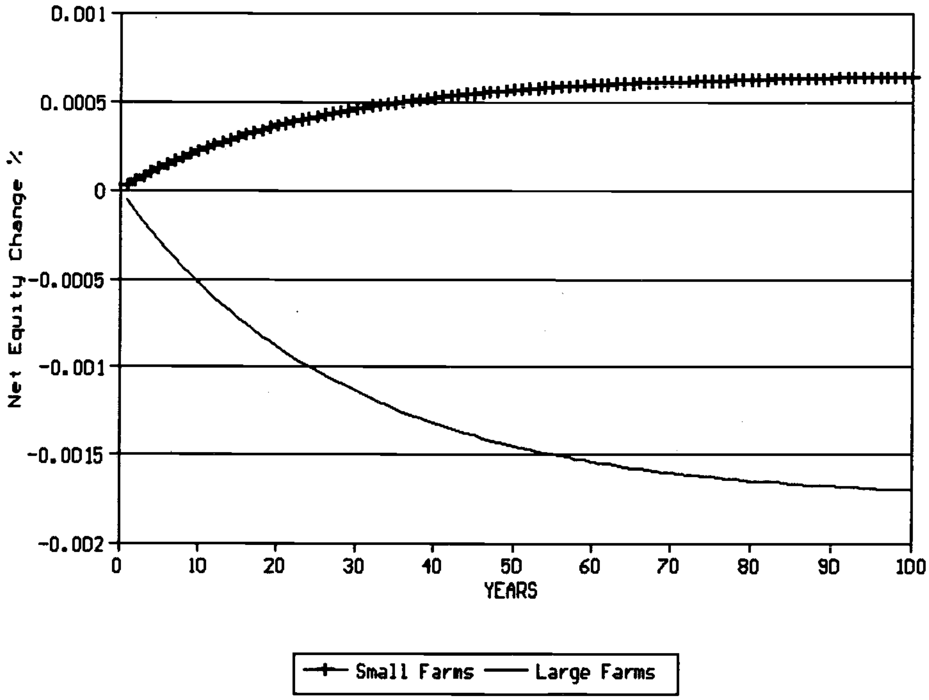

Figure 7.1. Effect of Paid Required Diversion Percentage on Net Equity.

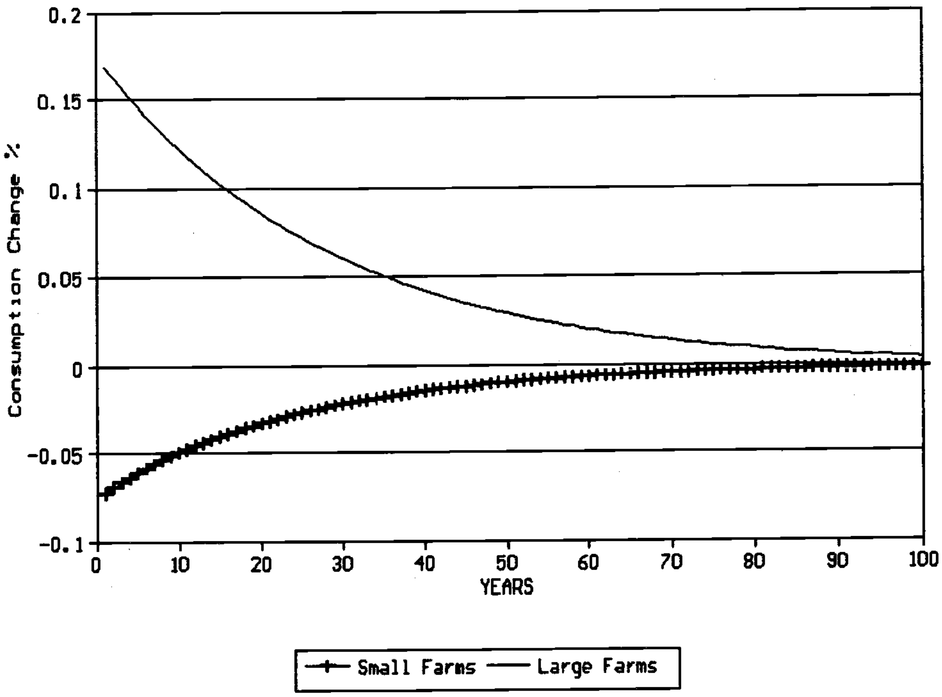

Figure 7.2. Effect of Required Paid Diversion Percentage on Consumption.

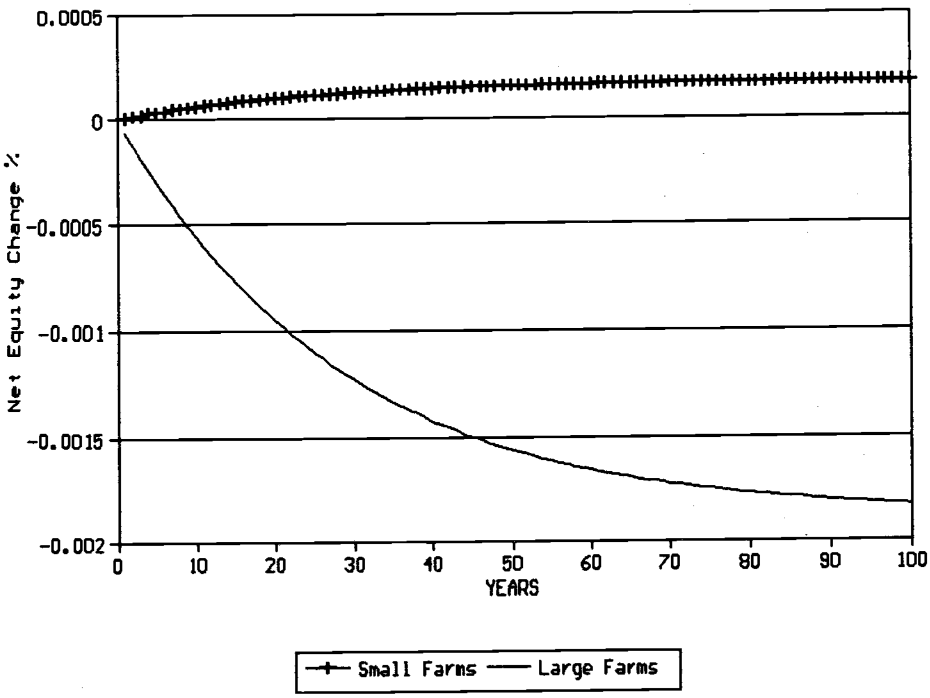

Figure 7.3. Effect of Unpaid Required Diversion Percentage on Net Equity.

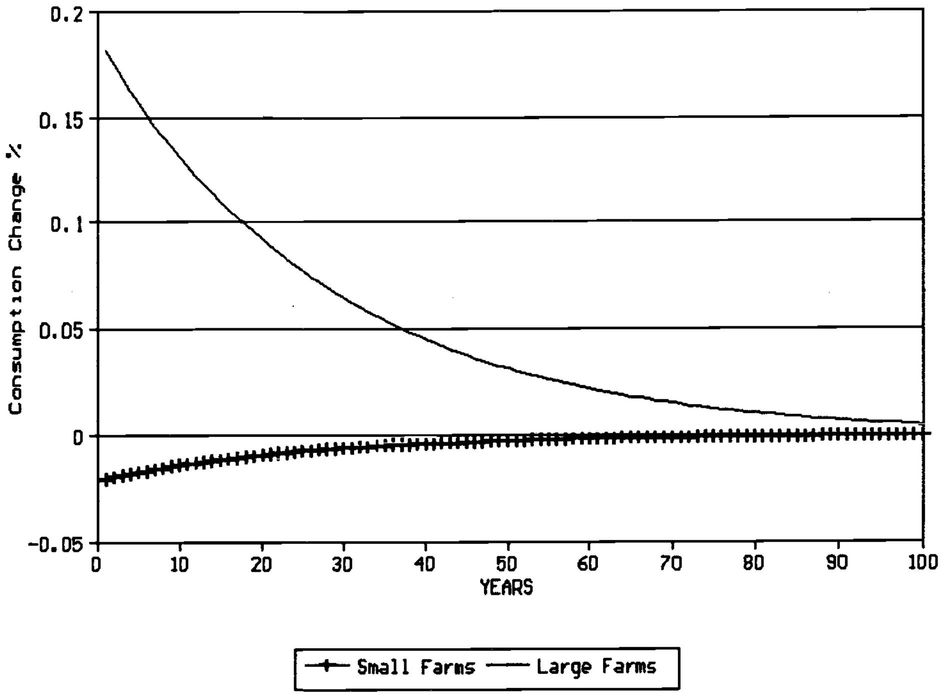

Figure 7.4 . Effect of Unpaid Required Diversion Percentage on Consumption.

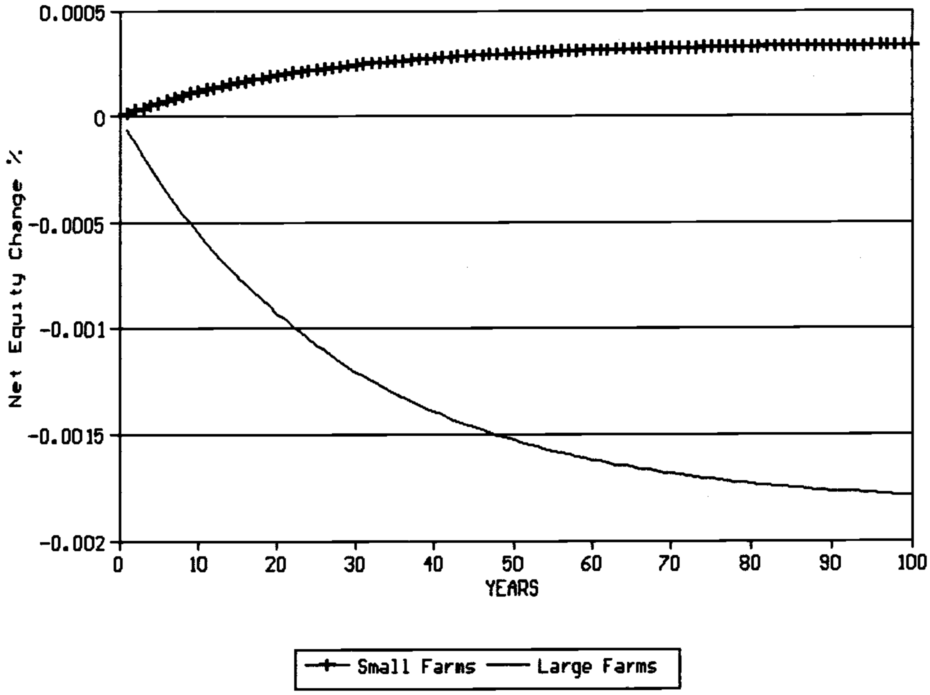

Figure 7.5 . Effect of Voluntary Diversion Percentage on Net Equity.

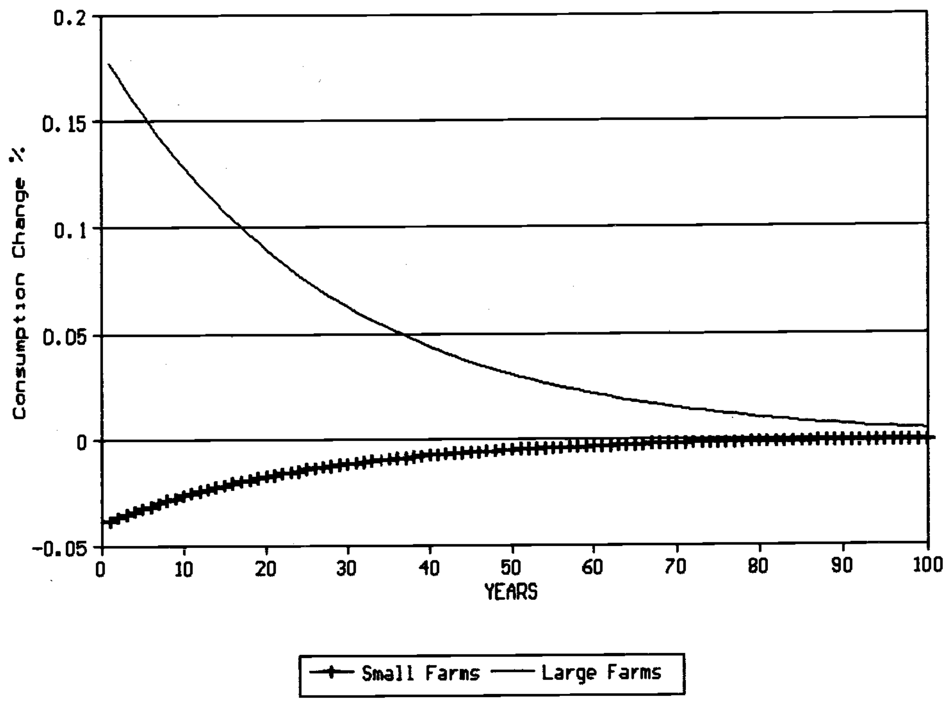

Figure 7.6 . Effect of Voluntary Percentage on Consumption.

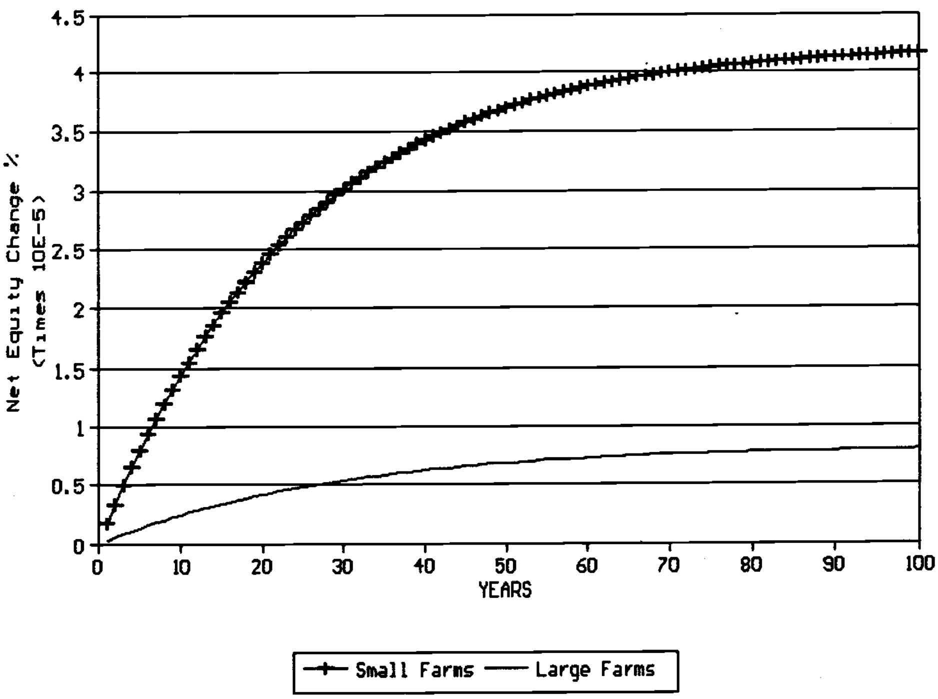

Figure 7.7 . Effect of Per-Acre Deficiency Payment Rate on Net Equity.

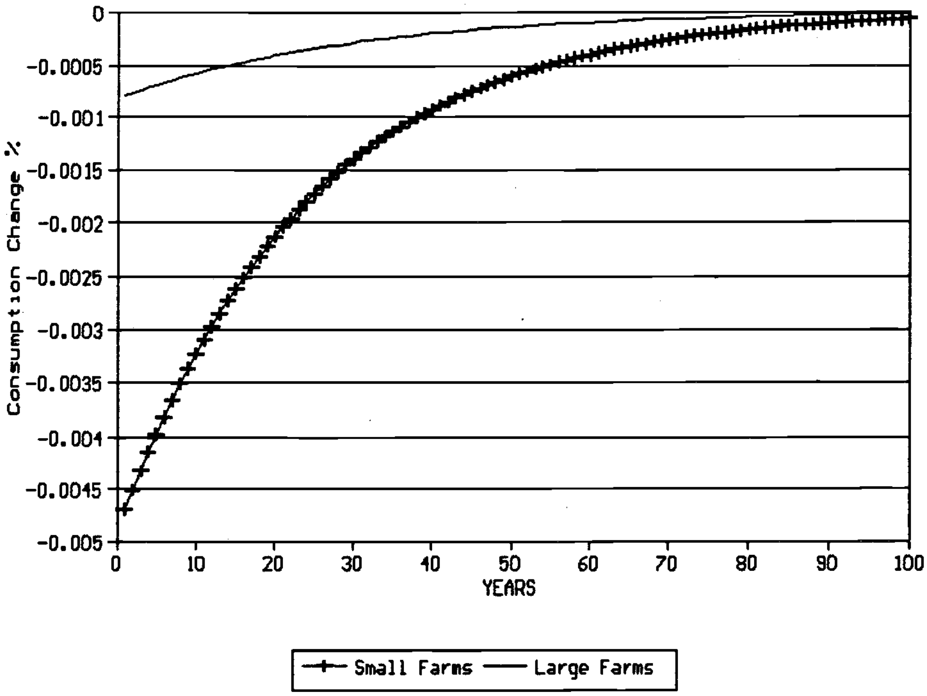

Figure 7.8 . Effect of Per-Acre Deficiency Payment Rate on Consumption.

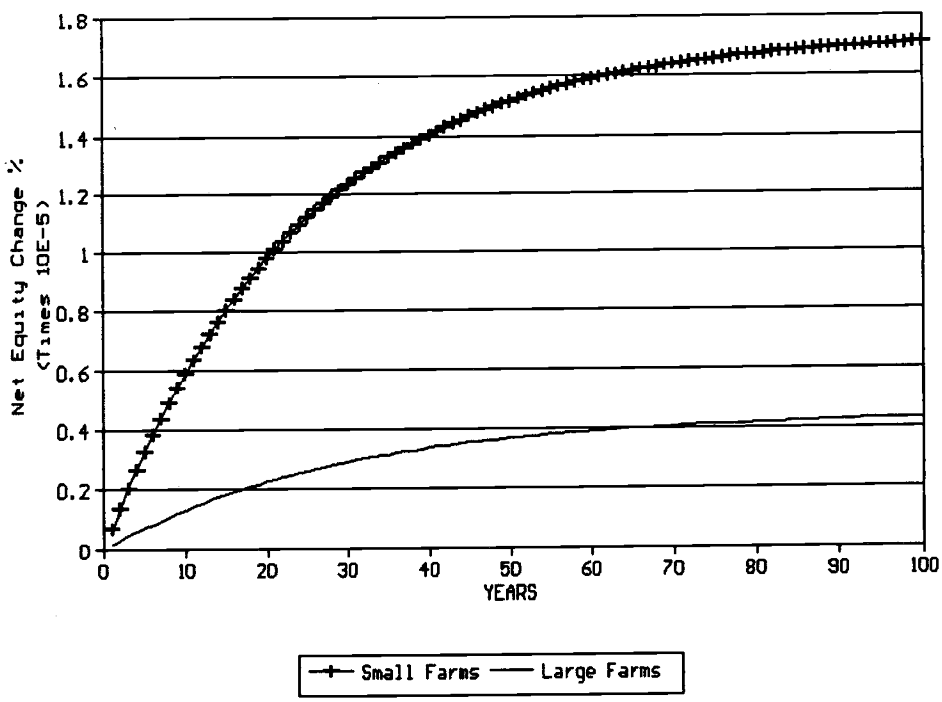

Figure 7.9 . Effect of Paid Required Diversion Payment Rate on Net Equity.

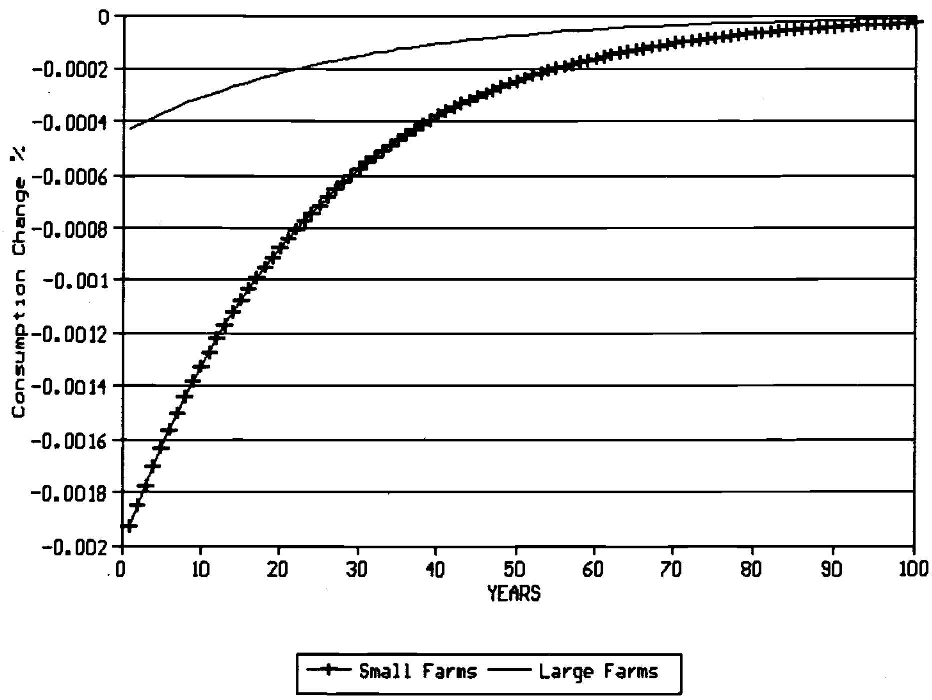

Figure 7.10 . Effect of Paid Required Diversion Payment Rate on Consumption.

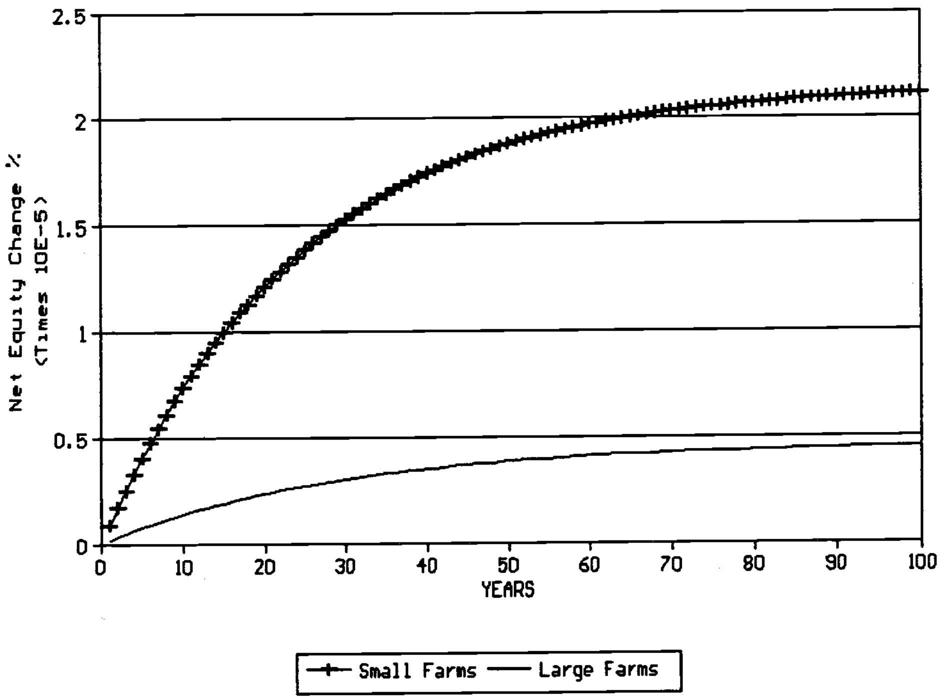

Figure 7.11 . Effect of Voluntary Diversion Payment Rate on Net Equity.

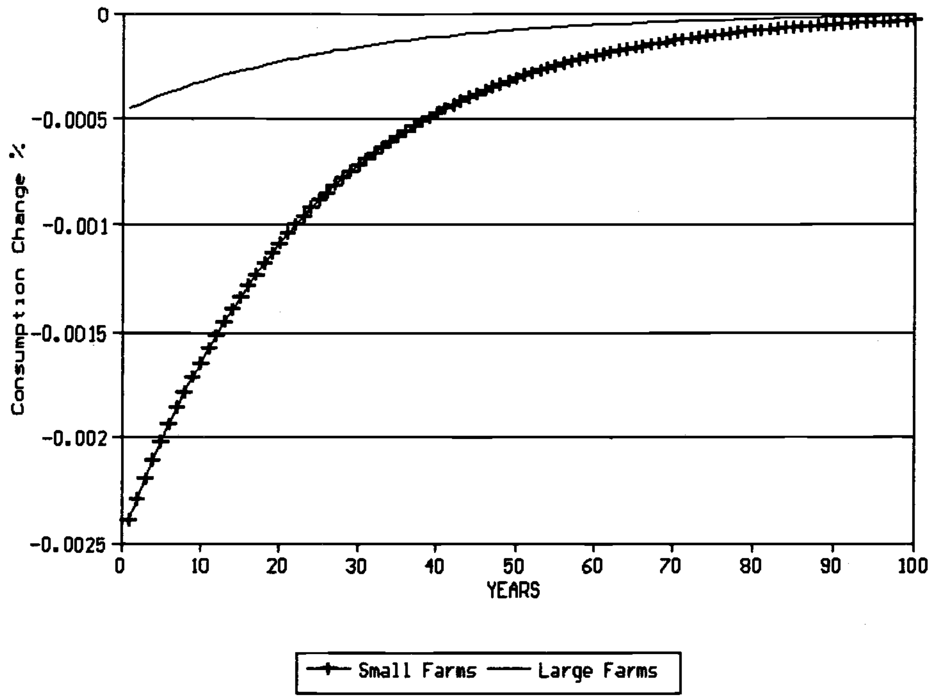

Figure 7.12 . Effect of Voluntary Diversion Payment Rate on Consumption.

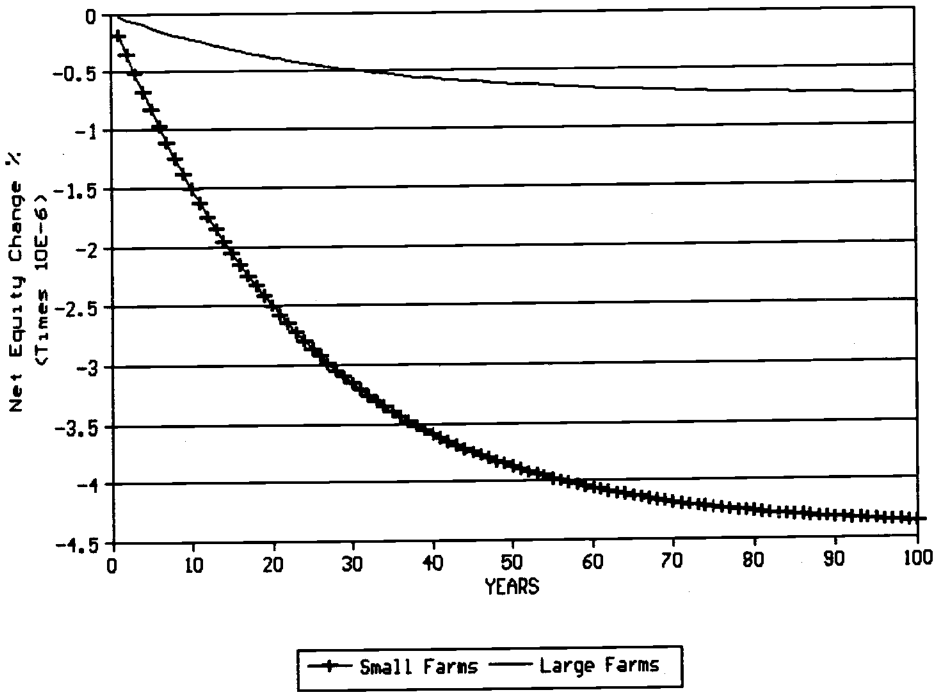

Figure 7.13 . Effect of Per-Acre Conservation Cost on Net Equity.

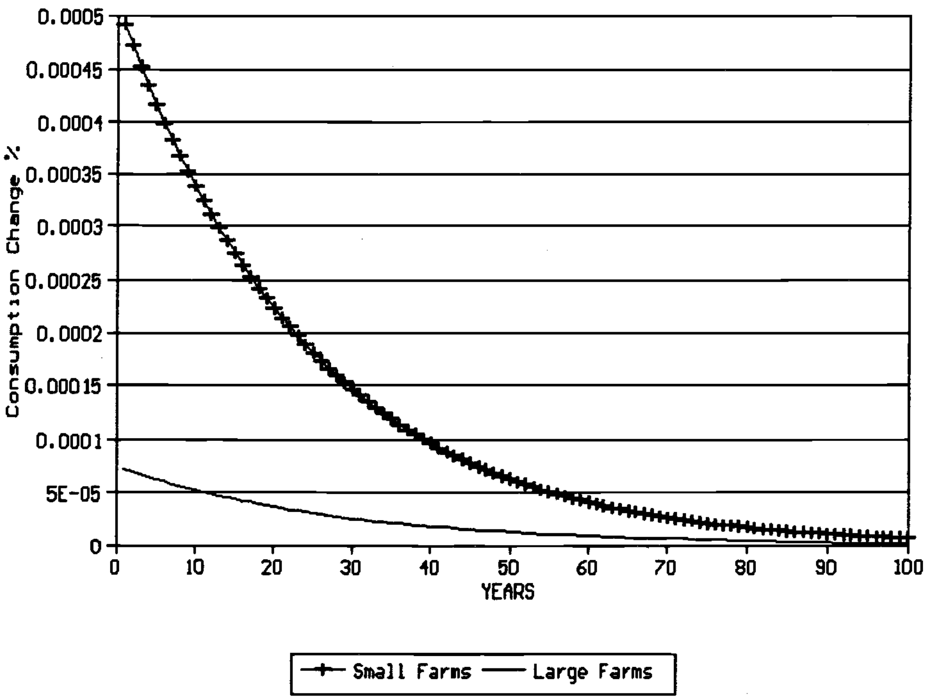

Figure 7.14 . Effect of Per-Acre Conservation Cost on Consumption.

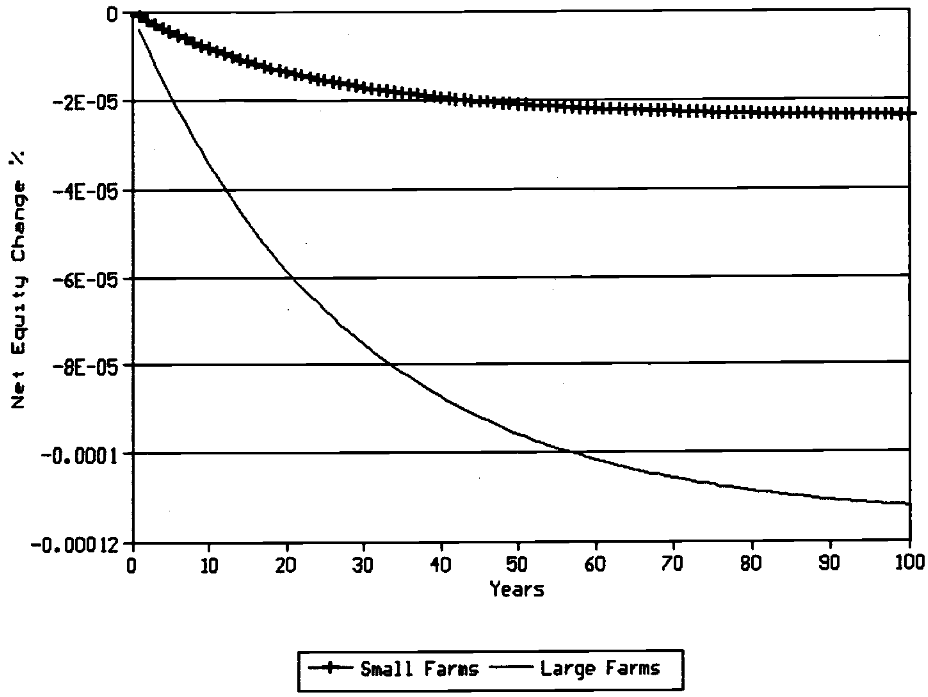

Figure 7.15 . Effect of Wheat Output Price on Net Equity.

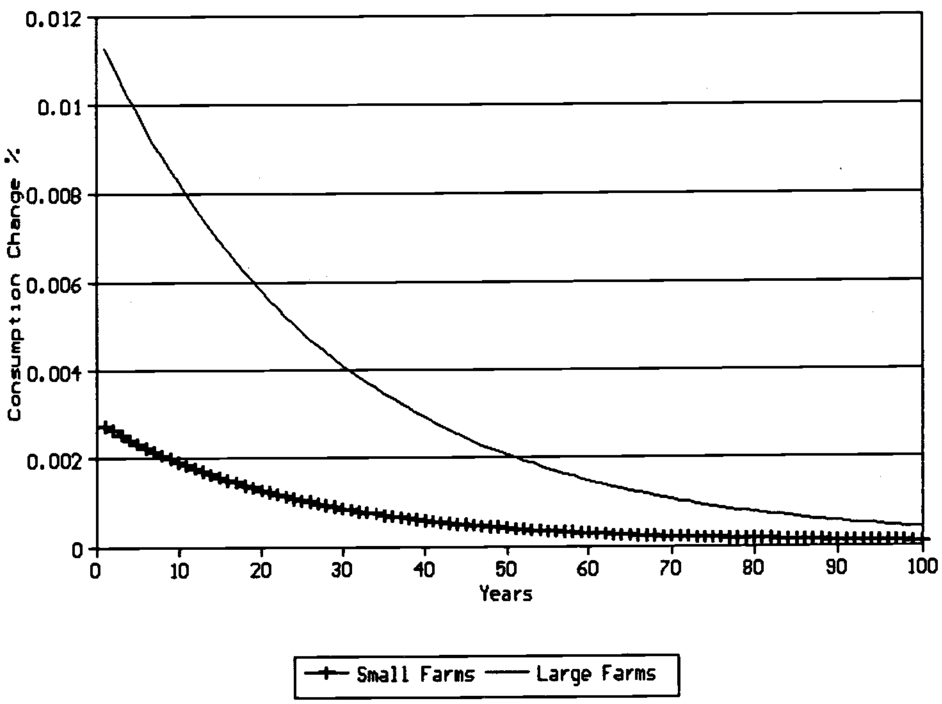

Figure 7.16 . Effect of Wheat Output Price on Consumption.

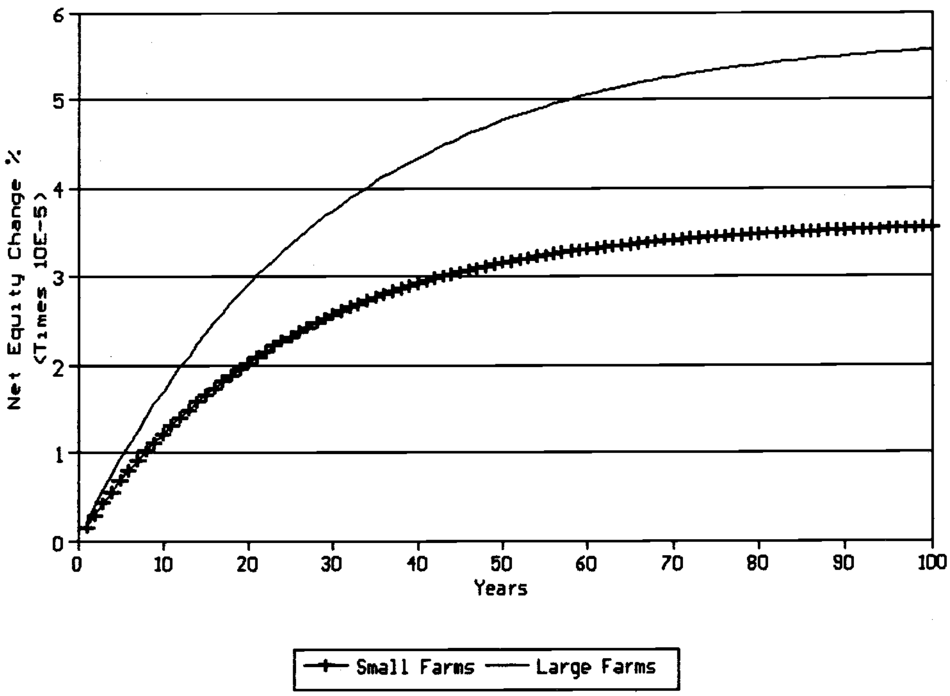

Figure 7.17 . Effect of Off-farm Wage Rate on Net Equity.

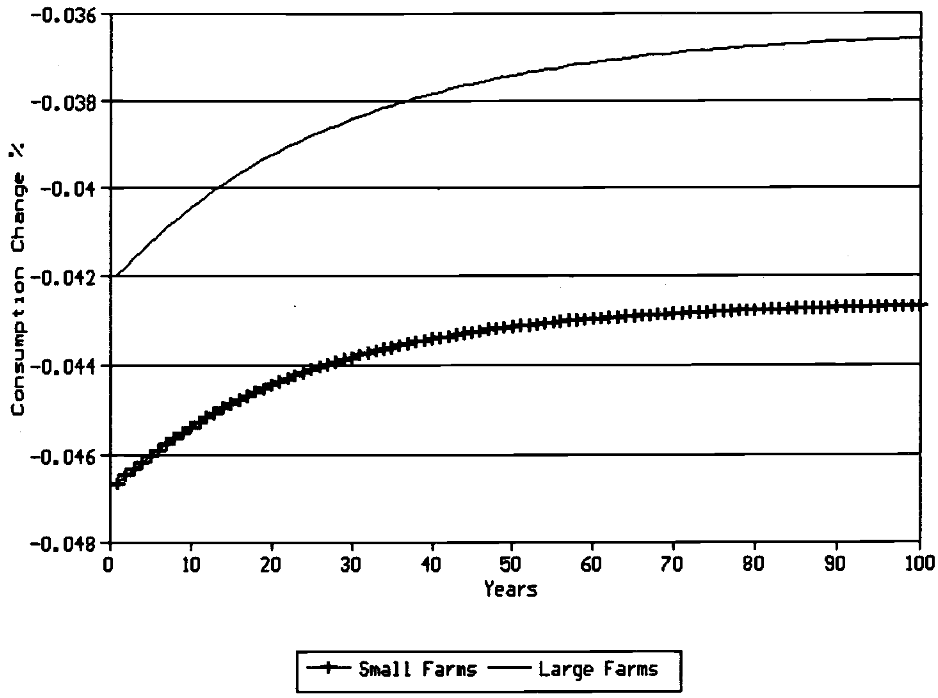

Figure 7.18 . Effect of Off-farm Wage Rate on Consumption.

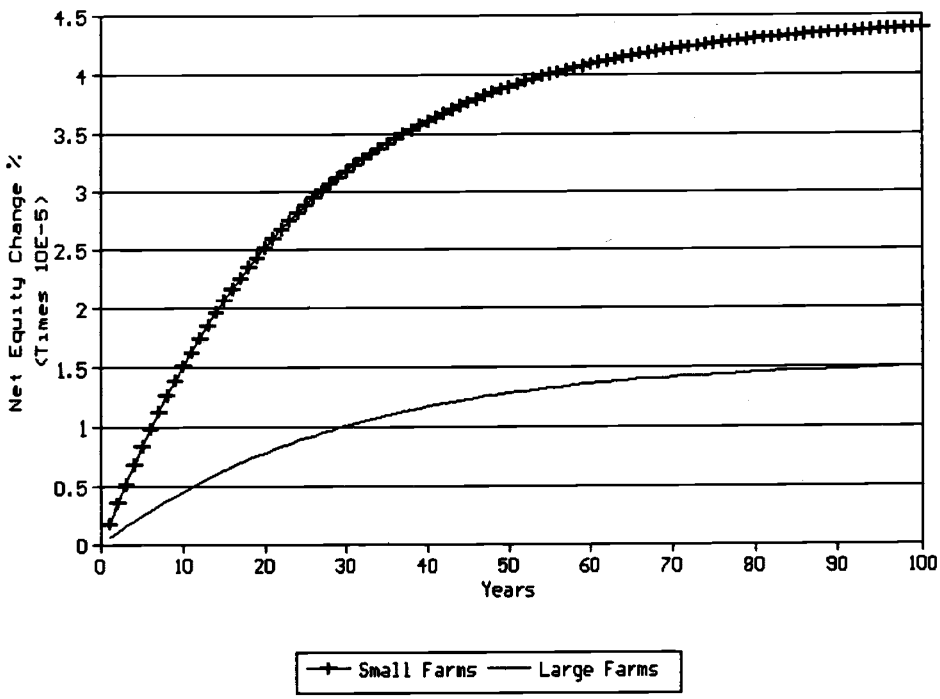

Figure 7.19 . Effect of Fertilizer Price on Net Equity.

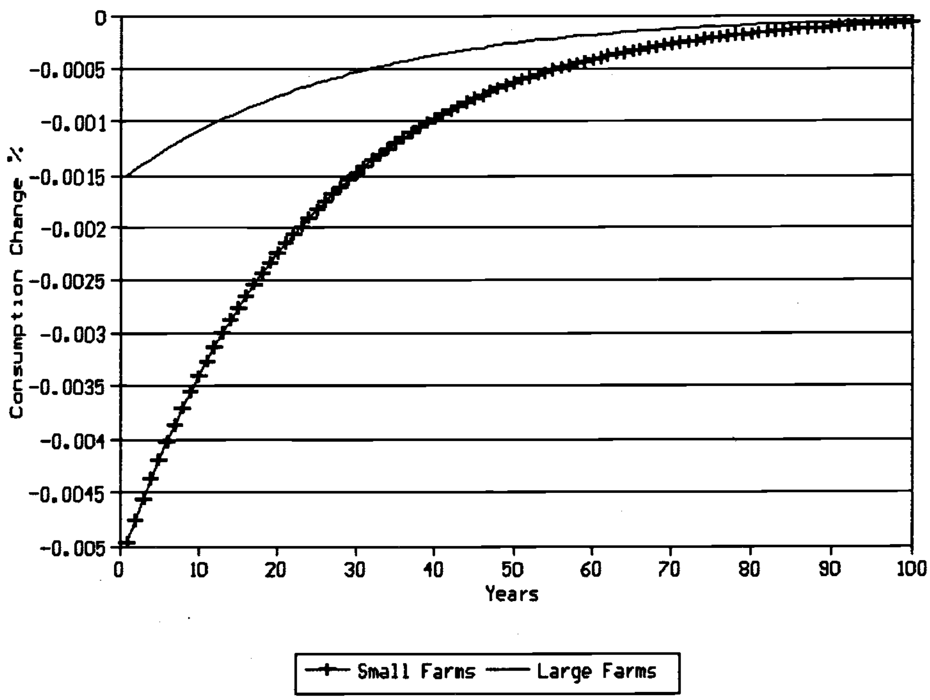

Figure 7.20 . Effect of Fertilizer Price on Consumption.

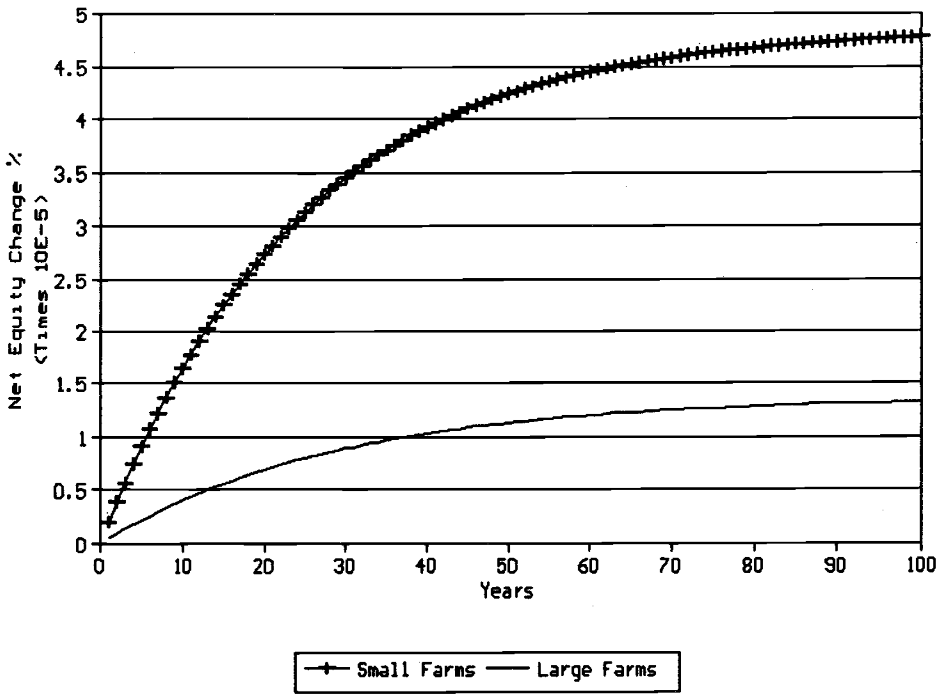

Figure 7.21 . Effect of Machinery Use price on Net Equity.

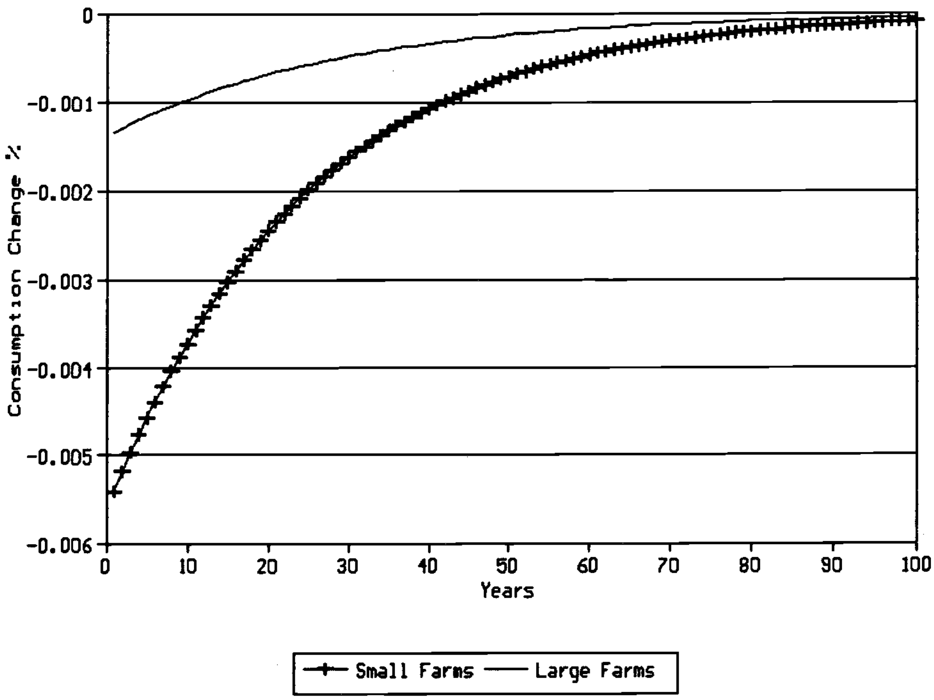

Figure 7.22 . Effect of Machinery Use price on Consumption.

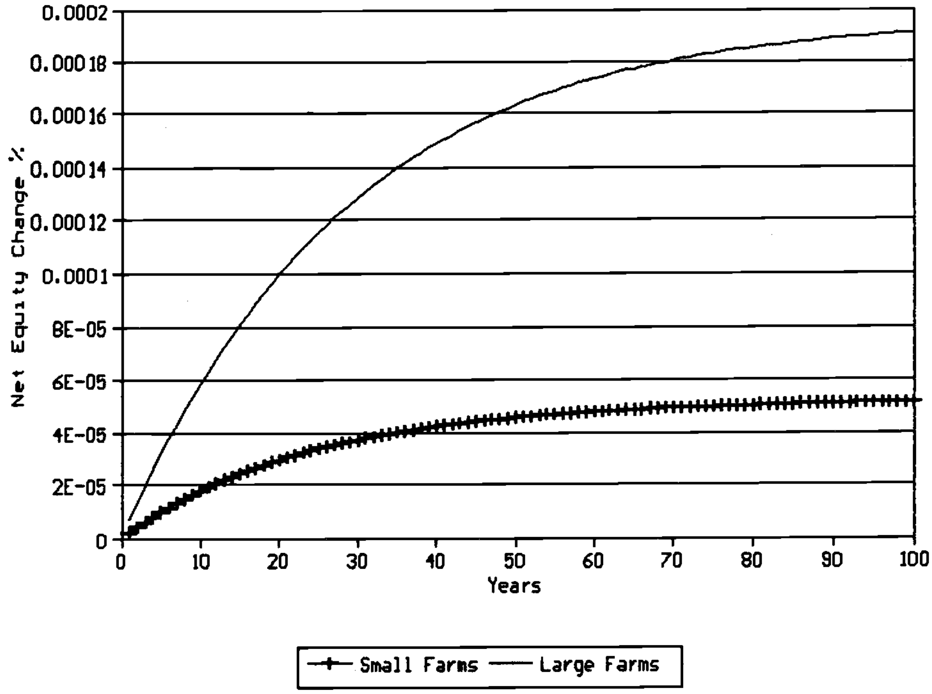

Figure 7.23 . Effect of Other Inputs Price Level on Net Equity.

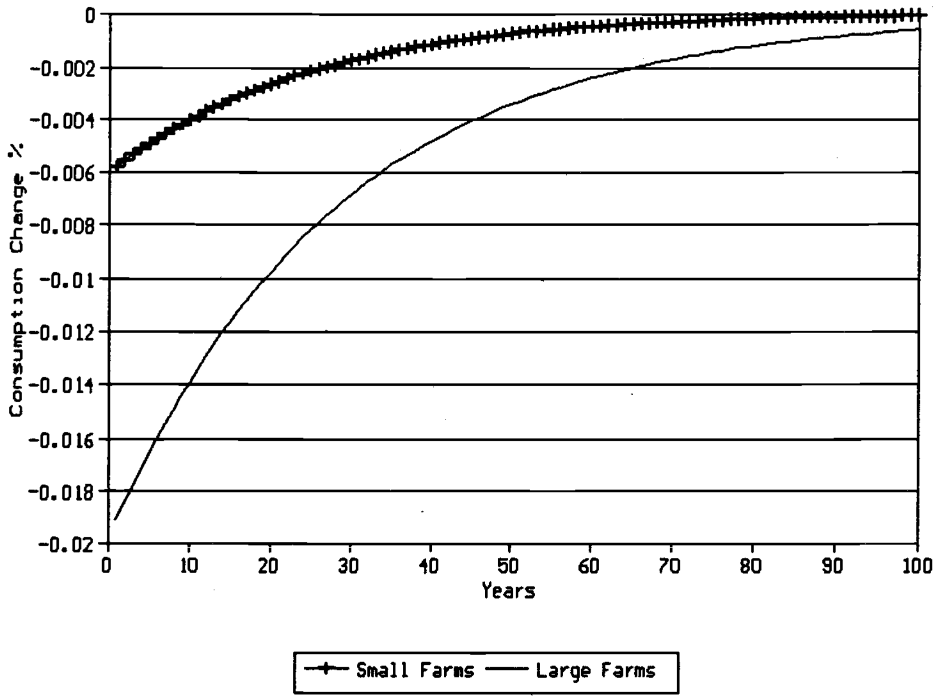

Figure 7.24 . Effect of Other Inputs Price Level on Consumption.

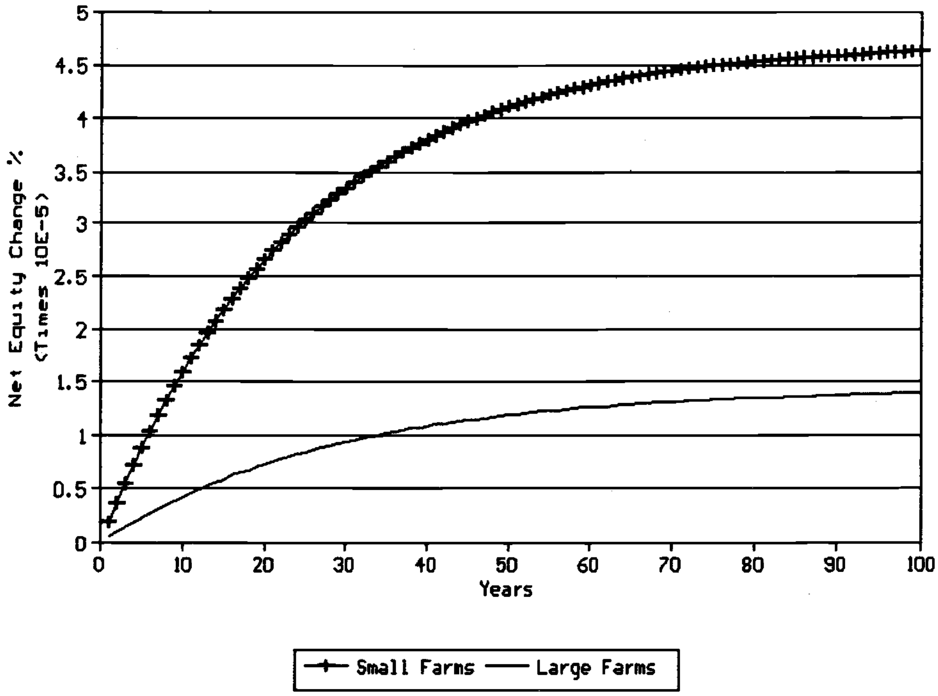

Figure 7.25 . Effect of Land Purchase Price on Net Equity.

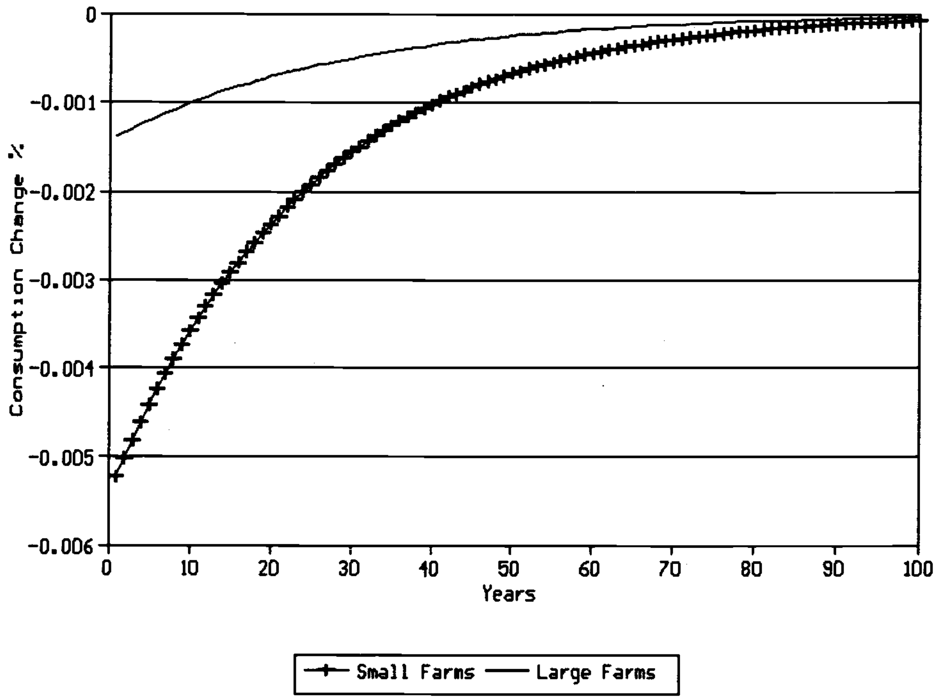

Figure 7.26 . Effect of Land Purchase Price on Consumption.

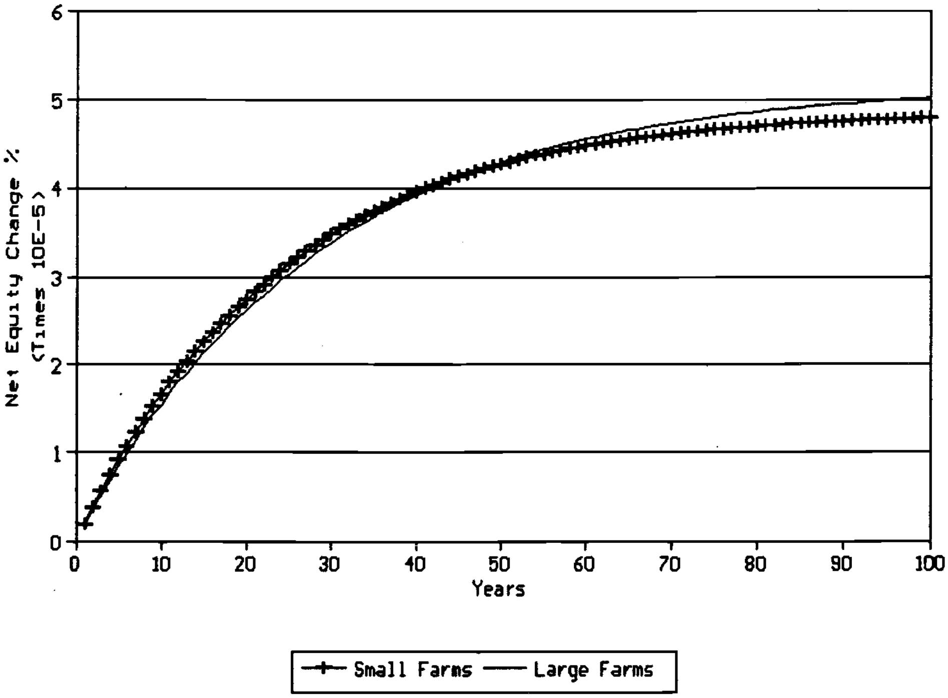

Figure 7.27 . Effect of Land Rental Rate on Net Equity.

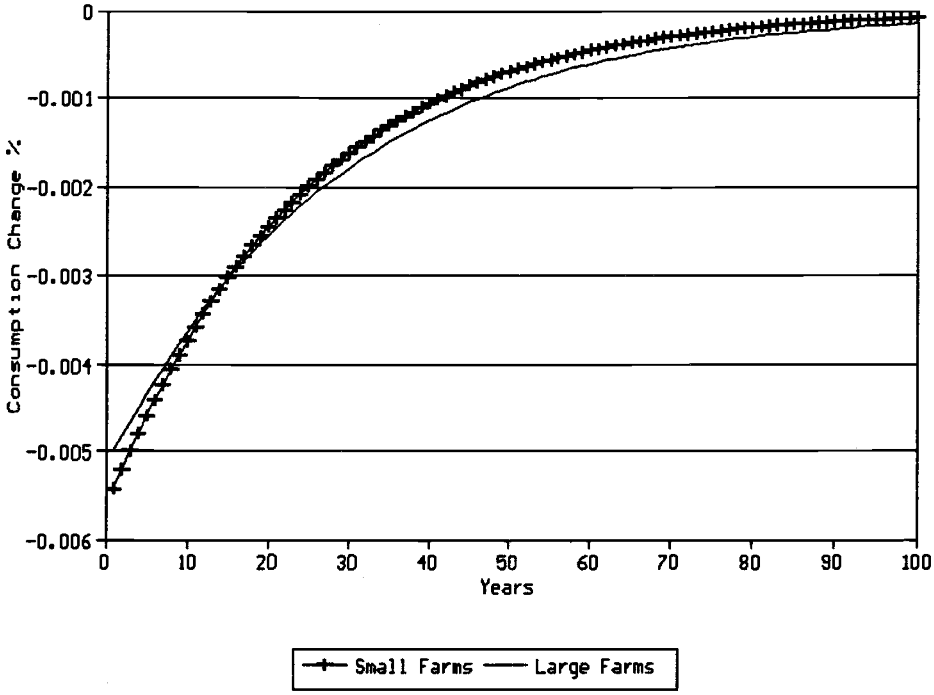

Figure 7.28 . Effect of Land Rental Rate on Consumption.

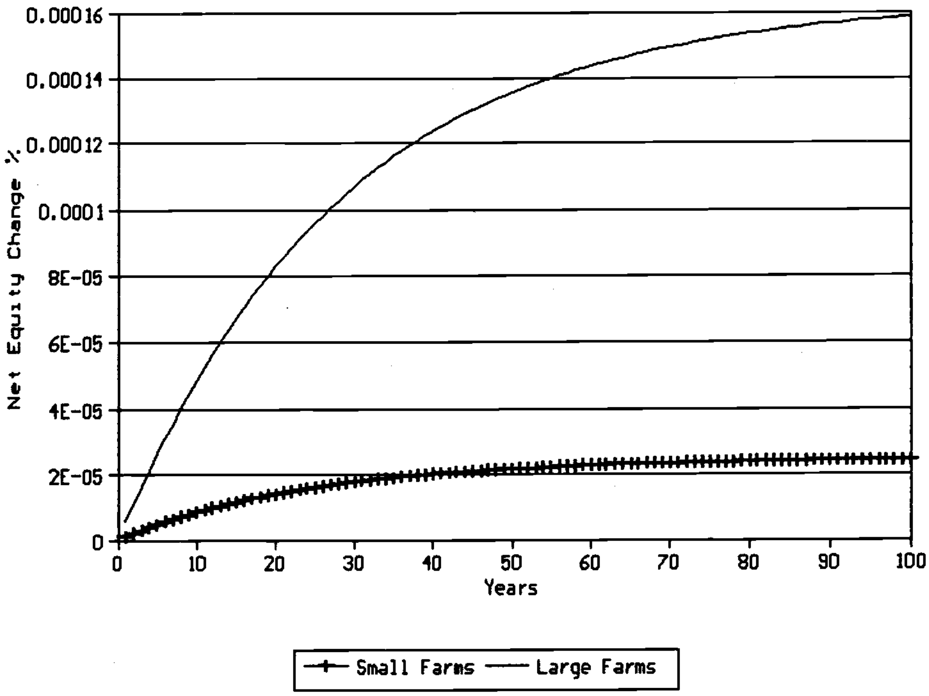

Figure 7.29 . Effect of Technical Change on Net Equity.

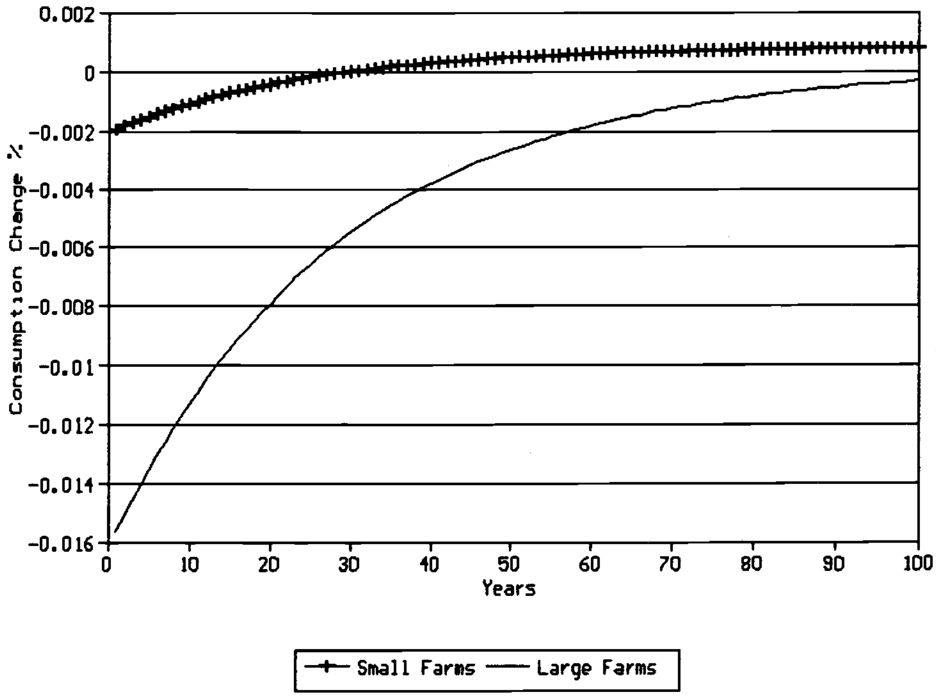

Figure 7.30 . Effect of Technical Change on Consumption.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This study analyses the farm-level, as opposed to aggregate, effects of farm commodity programs and variables on farm firm growth. It differs from previous studies by concentrating on microeconomic effects as opposed to aggregate program effects. The study also reveals the dynamic adjustment effects generally missing in most previous studies. The study develops propositions which are empirically examined using Kansas wheat farm data.

To achieve the study objectives, I develop a growth model linking consumption and production decisions. The resulting structural model incorporates off-farm labor and investment decisions; land rental, purchase, and selling behaviors; and the risk of farm failure. Performing steady-state comparative statics and local dynamics on the solutions of the dynamic model yields qualitative effects of commodity programs on farm firm growth. Empirical estimates of the qualitative effects are obtained for two size classes of farms using Kansas data.

A theoretical analysis of the model yields the following propositions:

RESULT 1. If the absolute value of the own price elasticity of owned land demand (σ) is low (as defined in Appendix I), then set-aside type program instruments - required diversion and voluntary diversion percentages -

have a positive effect on longrun net equity. Alternatively, if σ is high, these instruments have a negative effect on longrun net equity.

Result 1 says that when the absolute value of own price elasticity of demand for owned land is low, an increase in percentage set-aside increases the marginal income from a unit of net equity. This means that at the original steady state, marginal income from a unit of net equity (MIE) exceeds the discount rate. Thus, to get to the new equilibrium, the farmer increases net equity to the point where equilibrium between the marginal return on net equity equals the discount rate. If the price elasticity of land demand is high, the opposite occurs: an increase in percentage set-aside reduces the marginal return on net equity, and to re-establish an equilibrium, farmers must decrease net equity. Thus, percent set-aside instruments encourage paying off debt when σ is low, but encourage debt accumulation when σ is high.

RESULT 2. Increases in payment rate type instruments - voluntary diversion payment rate, support price, target price and program yield - all lead to long term increases in net equity.

Result 2 says that an increase in a government payment rate increases the marginal return on equity which, as pointed out earlier, encourages investment. Unlike the set-aside policies, payment rate policies increase total income to the farmer without imposing any restrictions on land planted, making land valuable.

RESULT 3. Increases in output price and effective loan interest rate have a negative long term effect on net equity.

Result 3 implies that an increase in output price or effective loan interest rate decrease the marginal return on net equity. This is apparent in the case of the interest rate since an increase in interest rate increases the cost of debt servicing. Cost increase reduces income per unit of net equity. In the case of output price, however, there is an increase in income, but most of the increase is taken up by consumption to the point that investible return per unit of net equity decreases.

RESULT 4. Raising the price of an input has a positive effect on long term net equity if the input is a substitute to land, and a negative effect if the input and land are complements.

If an input is substitute to land in production and its price is raised, the farmer saves money by increasing land. Since land is positively related to net equity, its value is also increased and the opposite happens if the input is complement to land.

RESULT 5. Increases in land purchase price have a positive longrun effect on net equity.

Result 5 is rather obvious. An increase in land purchase price increases the gross value of farm assets and also reduces the cost of debt servicing as the effective interest rate decreases. This increases net equity immediately and in the long term as more money is available in the present to finance investments.

Econometric estimations based on small farms and large farms, separately, yielded several illuminating results. First, coeficient estimates are significantly different between small and large farms. Of importance in explaining the effects of set-aside instruments is the result that own price elasticity of demand for owned land in large farms is approximately twice the size of that for small farms, in absolute terms. Also, the leisure to consumption ratio is significantly greater in large than in small farms. Empirical results also show that off-farm work is a significant source of income in small farms, but is not significant in large farms. Finally, estimated results do not support the hypothesis that there is a difference in cost of capital between small and large farms of comparable net equity positions.

The study generates growth effects of program and nonprogram variables based on the econometric estimates. For both small and large farms, longrun effects generally confirm the propositions discussed above.

Empirical results show that set-aside policy instrument effects on longrun net equity are positive in small farms and negative in large farms. This is in accordance with Result 1. For both size classes, set-aside policy instruments lead to a longrun decrease in consumption, an increase in landholding, and a decrease in rented land, in the longrun. However, only in the case of unpaid required diversion percentage in small farms is the change in landholding greater than in rented land. Thus, set-aside policy instruments do not change the scale of operation in either small or large farms. What they tend to do, however, is to increase the part of the farm that is farmer-owned. This increase is greater in large than in small farms. Large farmers borrow money to finance their growth, while small farmers achieve growth through savings. This is reflected in the longrun increase in net equity by small farms and decrease in net equity by large farms. Thus, set-asides as instruments to affect structure do little to bridge the size gap between large and small farms even though they foster healthier longrun financial conditions on small farms.

Quantitative effects indicate that payment rate instruments - support prices, target prices, program yield, voluntary payment rate, paid required diversion payment rate - have positive long term effects on net equity and consumption. Their longrun effects on landholding are positive in small farms and negative in large farms. For both small and large farms, payment rate instruments have positive longrun effects on rented land. These results suggest that payment rate instruments can help bridge the owned land size differences between small and large farms, while at the same time, reducing the tendency toward indebtedness and risk of financial failure. Even better for small farms, the rate of financial improvement after an increase in a payment rate is greater in small than in large farms. However, the scales of operation in large farms increase more than in small farms through aggressive use of the land rental market.

The present study also analyses the effects of nonfarm program variables. This is important from a policy perspective because some government policies, not directly related to agriculture, affect such variables. Thus, discussing the effects gives us a basis for including the nonfarm policies on farm growth.

Our empirical results show that, for both small and large farms, wheat output price has a positive effect on longrun consumption and rented land, but a negative effect on net equity and landholding. The percentage increases in rented land are greater than are thd decreases in landholding, implying an increase in scale of operation for both size classes. Thus, output price increases encourage high consumption, borrowing, and tenancy among all farm sizes.

An increase in land purchase price has a positive longrun effect on net equity, consumption, landholding, and rented land. Thus, an increase in land purchase price increases scale of operation, ownership, and the financial wellbeing of all farm sizes. The overall magnitude, in percentage terms, and the speed of the rate of adjustment is higher in small than in large farms. Thus we would expect factors that lead to an increase in land purchase price to have a more favorable impact on small than on large farms.

In both large and small farms, the off-farm wage rate has positive longrun effects on net equity and landholding, and a negative effect on longrun consumption. The longrun effect on the amount of rented land of an increase in off-farm wages is positive for small farms and negative for large farms. Thus on the whole, an increase in off-farm wage rate leads to a long term improvement in financial condition, landholding, and operated acreages on both small and large farms. The magnitude and rate of adjustment, in all the above effects, is higher on large than on small farms.

Farm variable input prices all have similar effects on farm growth in both size classes. All show positive longrun effects on net equity, landholding, and rented land. Thus, input price increases encourage better financial conditions and larger scales of operation. Differences among the effects are in magnitude and speed of adjustment. Increases in prices of fertilizer and machinery services result in larger percent increases and quicker, in small than in large farms. On large farms, increases in the price of the composite input result in effects which are higher in magnitude and rate of adjustment than they do in small farms. An increase in land rental rate leads to approximately similar adjustment paths on small as on large farms.

Our results show that technical advances have positive long term effects on consumption and net equity. In large farms, this is translated into longrun increases in landholdings and rented land and, hence, to larger operated acreages. In small farms, most of the gains from technical changes go to consumption. In small farms, technical change encourages divestment from land and increases in rented land. Thus, technical change leads to longrun increases in the size gap between large and small farms, a result akin to the "treadmill" prediction by Cochrane (1979).

Because they emphasize farm level growth effects, the results above do not take into account effects of program and non-program factors on asset prices. Nor does the present analysis endogenize a farmer's decision about whether to participate in commodity programs. Incorporating these two factors would provide a fuller account of effects on farm growth of farm programs and market variables.

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APPENDICES

Appendix I

Direct and Cross Effects of Net Equity, Program Instruments and Prices on the Income Function

This appendix derives direct and cross effects of net equity and prices on the income function, which are inputs into effects of prices and program instruments on steady state net equity and consumption, and hence local comparative dynamic effects.

Recall from Chapter II that for the participating farmer

$$\bar{q} = \frac{(q_0 - VG_0 - (1-S-V)(P^T - P')Y^0)}{(1-S-V)}$$

and

$$\bar{r} = \frac{(rP_L - VG_0 - (1-S-V)(P^T - P')Y^0)}{(1-S-V)}$$

Differentiating the above expressions with respect to program instruments and net equity we have:

$$\bar{r}_{G_0} = \frac{-V}{(1-S-V)} \quad < 0 \qquad \text{Since} \quad S + V < 1$$

$$\bar{r}_V = \frac{[\bar{r} + (P^T - P') - G_0]}{(1-S-V)} \quad \geq / < 0$$

$$\bar{r}_s = \frac{[\bar{r} + (P^T - P')]}{(1-S-V)} \quad > 0$$

$$\bar{r}_{r_0} = \frac{P_L}{(1-S-V)} \quad > 0$$

$$\bar{r}_{P_L} = \frac{r}{(1-S-V)} \quad > 0$$

$$\bar{r}_{P'} = Y^0 \quad > 0$$

$$\bar{r}_{P^T} = -Y^0 \quad < 0$$

$$\bar{r}_{Y^0} = -(P^T - P') \quad \leq 0$$

$$\bar{r}_E = \frac{P_L g'(E)}{(1-S-V)} \quad < 0$$ Since $g(\cdot)$ is increasing in E

$$\bar{q}_{G_0} = \frac{-V}{(1-S-V)} \quad < 0$$

$$\bar{q}_V = \frac{[\bar{q} + (P^T - P')Y^0 - G_0]}{(1-S-v)} \quad \geq / < 0$$

$$\bar{q}_S = \frac{[\bar{q} + (P^T - P')Y^0]}{(1-S-v)} \quad > 0$$

$$\bar{q}_{P'} = Y^0 \quad > 0$$

$$\bar{q}_{P^T} = -Y^0 \quad < 0$$

$$\bar{q}_{Y^0} = -(P^T - P') \quad \leq 0$$

$$\bar{q}_{q_0} = \frac{-1}{(1-S-V)} \qquad > 0$$

Further differentiating these partial effects with respect to E we get

$$\bar{r}_{EG_0} = \bar{r}_{EY^0} = \bar{r}_{EP'} = \bar{r}_{Er_0} = 0$$

$$\bar{r}_{EP_L} = \frac{g'(E)}{(1-S-V)} \qquad < 0$$

$$\bar{r}_{EV} = \bar{r}_{ES} = \frac{P_L g'(E)}{(1-S-V)^2} \qquad < 0$$

$$\bar{q}_{E\phi_i} = 0 \qquad \text{all i.}$$

The above effects help us derive the effects on income I_{ϕ_i} and $I_{E\phi_i}$ as follows. Applying the Envelope Theorem to the income function we have:

$$I_{q_0} = -A^r \bar{q}_{q_0} \qquad < 0$$

$$I_{G_0} = -A^0 \bar{r}_{G_0} - A^r \bar{q}_{G_0} \quad > 0 \quad \text{since } \bar{r}_{G_0}, \bar{q}_{G_0} < 0$$

$$I_S = -A^0 \bar{r}_S - A^r \bar{q}_S \quad < 0 \quad \text{since } \bar{r}_S, \bar{q}_S < 0$$

$$I_V = -A^0 \bar{r}_V - A^r \bar{q}_V \quad < 0 \quad \text{since } \bar{r}_V, \bar{q}_V < 0$$

$$I_{r_0} = -A^0\bar{r}_{r_0} + E$$
$$= \frac{-P_L A^0}{(1-S-V)} + E$$
$$= -\text{Debt} \quad \leq 0$$

$$I_{P_L} = -A^0\bar{r}_{PL} \quad < 0 \quad \text{since } \bar{r}_{PL} > 0$$

$$I_P = Y-(A^0+A^r)Y^0 \quad > 0 \text{ if } P^T > \max(\text{loan rate},P)$$

or (loan rate > P)

indeterminate otherwise.

$$I_{PT} = Y^0(A^0+A^r) \quad > 0$$

$$I_{Y^0} = Y^0(A^0+A^r)(P^T-P') \quad \geq 0$$

$$I_W = -X \quad < 0$$

Differentiating these effects with respect to net equity, E

we have:

$$I_{EGo} = -A_{\bar{r}}^{o} \cdot \bar{r}_E \cdot \bar{r}_{Go} \qquad > o$$

$$I_{ES} = A_{\bar{r}}^{o}\,\bar{r}_E\,\bar{r}_S - A^o \cdot \bar{r}_{ES}$$

$$= -P_L \cdot g'(E)\left[A_{\bar{r}}^{o}\,(\bar{r} + (P^T-P')Y^o) + A^o\right] / \left[(1-s-v)^2\right]$$

$$= -P_L \cdot A^o \cdot g'(E)\left[\bar{r} + (P^T-P')Y^o\right]$$

$$\cdot\left[\sigma + \bar{r}/(\bar{r} + (P^T-P')Y^o)\right] / \left[\bar{r}\,(1-s-v)^2\right]$$

$> o$ if $|\sigma| < \bar{r}/(\bar{r}+(P^T-P')Y^o) = k_s$

$\leq o$ otherwise

where $\sigma = A_{\bar{r}}^{o} \cdot \bar{r}/A^o$ = owned land demand elasticity

$$I_{EV} = -A^{o}_{\bar r} \cdot \bar r_E \cdot \bar r_v - A^o \cdot \bar r_{EV}$$

$$= -P_L \cdot A^o \cdot g'(E)\left[\sigma + \bar r/\left[r + (P^T - P')Y^o - G_o\right]\right] \cdot$$

$$\left[r + (P^T - P')Y^o - G_o\right] / \left[r\,(1-s-v)^2\right]$$

$$>o \text{ if } |\sigma| < \bar r/(\bar r + (P^T - P')Y^o - G_o) = k_v$$

$\leq$o otherwise.

$$I_{EY^o} = -A^{o}_{\bar r} \cdot \bar r_E \cdot \bar r_{Y^o} - A^o\, \bar r_{EY^o}$$

$$= -A^{o}_{\bar r} \cdot \bar r_E \cdot \bar r_{Y^o} \quad >o \quad \text{since } \bar r_{Y^o}, \bar r_E < o$$

$$I_{Er_o} = -P_L \cdot A^{o}_{\bar r} \cdot \bar r_E/(1-s-v) \quad <o$$

$$I_{EP^T} = -A^{o}_{\bar r}\, \bar r_E\, \bar r_{P^T} \quad >o$$

$$I_{EP} = -A^{o}_{\bar r}\, \bar r_p\, \bar r_E \quad \geq/<o \text{ since } \bar r_p \text{ is indeterminate}$$

$$I_{Eq_o} = -A^{r}_{\bar r} \cdot \bar r_E \quad >o \text{ since } A^r \text{ and } A^o \text{ are always substitutes}$$

$$I_{EP_L} = -A^{o}_{\bar r}\, \bar r_{P_L} \cdot - A^o\, \bar r_{EP_L}$$

$$= -P_L\, g'(E)\left[A^{o}_{\bar r}\, r/(1-s-v) + A^o\right] / (1-s-v)$$

$$= -P_L\, g'(E) A^o \cdot r[\sigma + (1-s-v)/r] / \left[r(1-s-v)^2\right]$$

$$>o \text{ if } |\sigma| < \frac{(1-s-v)}{r} = k_{PL}$$

$\leq$o otherwise

$I_{EW} = X_{\bar{r}} \bar{r}_E$ >o if X and A^o are substitutes

<o if X and A^o are complements

$I_{W_oW} = -L_{1w}$ >o if L_1 and A^o are substitutes

$= -L_{1W}$ <o if L_1 and A^o are complements

$I_{W_oG_o} = -L_{1\bar{r}} \cdot \bar{r}_{G_o} - L_{1\bar{q}} \bar{q}_{G_o}$ >o if L_1 is substitute to A^o and A^r

<o if the reverse is true

$I_{W_oV} = -L_{1\bar{r}} \bar{r}_V - L_{1\bar{q}} \bar{q}_V$ ≥/<o

since $\bar{r}_V$, $\bar{q}_V$ are both indeterminate

$I_{W_oS} = -L_{1\bar{r}} \bar{r}_S - L_{1\bar{q}} \bar{q}_S$ <o if L_1 issubstitute to both A^o and A^r

>o if they are complements

$I_{W_oP^T} = -L_{1\bar{r}} \bar{r}_{P^T} - L_{1\bar{q}} \bar{q}_{P^T}$ >o if L_1 is substitute to both A^o and A^r

<o if they are complements

$I_{W_oP_L} = -L_{L\bar{r}} \bar{r}_{P_L} - L_{1\bar{q}} \bar{q}_{P_L} = -L_{1\bar{r}} \bar{r}_{P_L}$

<o if L_1, and A^o are substitutes

>o if L_1, andA^o are complements

$$I_{W_o q_o} = -L_{1\bar{r}}\,\bar{r}_{q_o} - L_{1\bar{q}}\,\bar{q}_{q_o} = -L_{1\bar{q}}\,\bar{q}_{q_o}$$

<o if L_1 and A^r are substitutes

>o if L_1 and A^r are complements

$$I_{W_o Y^o} = -L_{1\bar{r}}\,\bar{r}_{Y^o} - L_{1\bar{q}}\bar{q}_{Y^o}$$

≥o if L_1 and A^o, L_1 and A^r are substitutes

≤o if L_1 and A^o, L_1 and A^r are complements

Appendix II

Cholesky Decomposition

This appendix gives an example of a Cholesky reparameterization for a three input quadratic profit function.

Following Lau (1978, in Fuss and McFadden, p. 438) reparameterizing the Hessian matrix B we have

$$\mathbf{B} \equiv \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{12} & B_{22} & B_{23} \\ B_{13} & B_{23} & B_{33} \end{bmatrix} \equiv LDL'$$

$$\equiv \begin{bmatrix} 1 & 0 & 0 \\ L_{21} & 1 & 0 \\ L_{31} & L_{32} & 1 \end{bmatrix} \begin{bmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} \begin{bmatrix} 1 & L_{21} & L_{33} \\ 0 & 1 & L_{32} \\ 0 & 0 & 1 \end{bmatrix}$$

$$\equiv \begin{bmatrix} d_{11} & L_{21}d_{11} & L_{31}d_{11} \\ L_{21}d_{11} & L_{21}^2 d_{11}+d_{22} & L_{21}L_{31}d_{11}+L_{31}d_{22} \\ L_{31}d_{11} & L_{21}L_{31}d_{11}+L_{31}d_{22} & L_{31}^2 d_{11}+L_{32}^2 d_{22}+d_{33} \end{bmatrix}$$

Solving the recursive system of relationship between B_{ij}'s and d's and L's we get the following explicit representation of d_{ii} as functions of elements of the Hessian matrix:

$$d_{11} = B_{11}$$

$$d_{22} = B_{22} - B_{11} (B_{12}/B_{11})^2$$

$$d_{33} = B_{33} - B_{11} (B_{13}/B_{11})^2$$

$$- [B_{13} - B_{12} \cdot B_{13}/B_{11}]^2/[B_{22} - B_{11} (B_{12}/B_{11})^2]^2$$