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A Generalized Model of Investment with an Application to Finnish Hog Farms

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A GENERALIZED MODEL OF INVESTMENT WITH AN APPLICATION TO FINNISH HOG FARMS

By

Kyösti Sakari Pietola

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

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ABSTRACT

A GENERALIZED MODEL OF INVESTMENT WITH AN APPLICATION TO FINNISH HOG FARMS

This study develops a method for estimating a generalized investment model. Irreversible investment behavior is allowed to arise either from generalized adjustment costs, uncertainty, or both. The model is estimated using data for a group of Finnish hog farms over the period 1977-93. Two out of four decision variables are allowed to obtain zero value with positive probability. The sample is endogenously partitioned into the regimes of zero and positive investments (four regimes in total). Then, the decision rules are estimated using the Full Information Maximum Likelihood (FIML) method. The model has a similar structure as the censored Tobit model.

The goal of the study is to find out the effects of frictions caused by uncertainty, irreversibility, and adjustment costs on investments in Finnish hog farms. External restrictions, such as liquidity constraints caused by credit rationing are also studied. The study's main goal is to obtain estimates for adjustment rates, elasticities, and shadow prices such that we account for the fact that optimal investments may be zero.

The results suggest that there are scale economies among Finnish hog farms and, in addition, scale effects in their investments. Thus, production costs per unit decrease as the amount of production increases. The instantaneous cost function is decreasing in investment so that larger investments will result in lower adjustment costs. These results suggest that

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Finnish pork producers have potential for improving their competitiveness by establishing large production units through drastic expansions.

It is expected that the Finnish hog industry has the potential for reaching the average cost level of Danish hog industry in 1995. Reaching the Danish cost level, however, will require Finnish production units to at least triple their size. Tripling the average firm size while keeping the aggregate production capacity constant, as required by hog adjustment programs, implies that two thirds of the current producers will need to exit the industry. Over a five year period, for example, this would require an exit rate of 8 % per year, which is almost twice the 4.3 % average exit rate of 1996 in Finnish agriculture. Therefore, it is expected that an inflexible labor market, combined with excess labor in farming, will delay the substitution of capital for labor and slow down the whole adjustment process.

The shadow price estimates show that Finnish hog farms have had excess capital relative to their exogenously restricted production levels. Hog farmers appear to have unconstrained access to capital. It is expected that increasing firm size will eventually result in more efficiently utilized and allocated farm capital. Still, low returns to farm capital cause severe difficulties in the farmers' adjustment to new market conditions. The results provide evidence that farm investments have been made with too low returns to capital or, alternatively, additional incentives for investments have been provided, for example, through investment programs or through tax shields.

Because the hog industry exhibits substantial economies of size, inflexible environmental regulations combined with rigidities in the local land markets are expected to have increasingly important effects on the development of hog industry structure and production costs.

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I am pleased to acknowledge the contribution and encouragement of people who have helped me towards completing this study and my Ph.D. degree.

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Finally, I thank my family for their support and especially you, Liisa, for your love and care.

East Lansing, April 1997 Kyösti Pietola

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Chapter 1

INTRODUCTION

1.1 Background

Uncertainty about continuation of the national agricultural policy scheme in Finland increased in 1991, when the political debate about Finland joining the European Union (EU) began. Four years later, in 1995, Finland joined the EU, adopted the price mechanism of the Common Agricultural Policy (CAP), and abolished border controls for trade with other member states. Membership in the EU has created a challenge for Finnish agriculture and the Finnish hog industry in particular. The average producer price of pork immediately fell by about 50 percent. But EU membership also resulted in a decrease in costs of hog production as grain prices went down, environmental taxes on phosphorus and nitrogen used in fertilizers were abolished, and the European Value Added Tax (VAT) was introduced. Although the output price declines have been partially compensated by reduced input prices and by income transfers, most farmers have yet to respond to the changed market environment and adjust their production to the increased competition in order to maintain an adequate income level (Ministry of Agriculture and Forestry 1996).

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Finnish agriculture is dominated by livestock production, and the hog sector is the third largest livestock production sector after milk and beef. In 1995 the hog sector accounted for 14 % of total agricultural gross returns. The hog production sector also creates an important market for domestic feed grains, including barley and oats. In Finland, the whole food industry is closely related to domestic agricultural production and, in particular, to the dairy and meat sectors. The food industry is the third most important industrial sector in Finland, while slaughtering, meat processing, and related industries are one of the largest sectors within the food industries (Aaltonen 1996). The future role of the Finnish hog industry is therefore important to Finland's economy.

Most hog farms in Finland are too small to use modern production technology as efficiently as their European competitors. Danish hog farms, for example, have herd sizes about twice as large as Finnish hog farms. Previous studies have shown that the differences in production costs, and in overall efficiency, between existing small and large farms are large (Hemilä 1983, Heikkilä 1987, Ryhänen 1992). This can also be supported simply by comparing production costs between the small and large production units. Thus, an increase in the size of production units offers a promising way to increase the competitiveness of Finnish agriculture.

But a shortcoming of the earlier studies in analyzing size economies has been their assumption that firms operate in a static environment with no uncertainty. They have assumed that firms can accumulate capacity all at once by increasing the stock of capital, or that the accumulation is exogenously restricted. Thus, they implicitly assume that individual firms operate at the long-run optimum, given exogenous prices, output or/and fixed inputs

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fixed inputs. It is likely that biased estimates of size economies are generated in static studies, because they ignore frictions that prevent instantaneous and costless adjustment of employment and the capital stock. Firms do not necessarily operate at their long-run optimum, and the implicit assumption of a static environment is not generally valid. In general, the link between the optimal capital stock and the optimal investment pattern cannot be established in a static framework.

Firms face two types of time dependent frictions; irreversibility and adjustment costs (Lucas 1967, Arrow 1968, and Abel and Eberly 1994). Most farm investments are at least partially irreversible. Once investments have been made, it will be expensive to reverse them for four reasons. First, there may be a wedge between the purchase prices and the resale prices of industry or firm specific capital goods (Arrow 1968). The wedge also can be caused by the adverse selection problem (Akerlof 1970), or by institutional rationing or transaction costs (Pindyck 1991). Second, strictly positive adjustment costs may be faced with negative investments (Caballero 1991). Third, the adjustment cost function may have a kink at the point of zero investment so that there may be a corner solution at zero. And fourth, fixed adjustment costs may be faced with even a small investment or disinvestment (Dixit and Pindyck 1994).

Irreversibility is important in investment problems, since it makes investment expenditures sunk costs that cannot be recovered, or can be recovered only partially. If, in addition, investments can be delayed, irreversibility makes them especially sensitive to uncertainty (Pindyck 1991). Uncertain future cash flows create a value for an option to wait for new, but never complete information. Therefore, less investment will be triggered th

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triggered than the traditional NPV rule suggests (Dixit and Pindyck 1994). The more volatile the expected future cash flows are, the more the ability to delay irreversible investment will affect the decision to invest[1].

Adjustment costs are costs that are realized when new capital is installed. They are traditionally thought of as being increasing and convex in the firm's investment and, therefore, they penalize rapid changes in the firm's capital stock, which results in investment smoothing (Lucas 1967, Treadway 1970, and Rothschild 1971). In this framework, the firm's capital stock is linked across time by adjustment costs. The stock cannot be adjusted instantaneously, as can variable factors in static models, but it can be changed, unlike fixed factors, as time passes by. In other words, the time pattern of the capital stock is endogenously decided by the entrepreneur, but there can be a substantial discrepancy between the firm's desired and actual capital stock, with the latter being less volatile than the former (Lucas 1967).

Adjustment costs can arise from internal or external causes (Mussa 1977). Internal adjustment costs are realized if scarce resources (inputs) need to be withdrawn from production to install new capital stock, resulting in reduced output (Lucas 1967). Similarly, with an exogenously determined output, internal adjustment costs will be realized in terms of increased costs. Internal adjustment costs can result, for example, from lack of information about new technology and from inflexible design of durables. External adjustment costs, on the other hand, cannot be controlled by firms themselves.

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[1] Pindyck (1991) compares the investment option to a financial call option; the option gives the holder the right to exercise the option and in return receive an asset. Exercising the option is irreversible.

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They can arise, for example, in a rationed credit market, or if the cost of borrowing increases with a firm's debt to equity ratio as its credit reserve decreases (Steigum 1983, Eichberger 1989, Robison and Barry 1996, Zeldes 1989).

Numerous empirical applications rationalize the observed spread of aggregate investment over time by adjustment costs which are assumed to be increasing and convex functions of the rate of investment. But the arguments supporting the idea that adjustment costs are an increasing and convex function of investment are weak. Decreasing adjustment costs are just as plausible as increasing adjustment costs (Rothschild 1971). In aggregate data, the observed spread of investment over time may not have resulted from investment smoothing of individual firms but from aggregating the individual firm's responses over firms. Estimated investment smoothing in firm level data, on the other hand, may have resulted from the fact that the discrete characteristics of the investment behavior have not been accounted for.

There also exists an extensive literature on the theory of irreversible investment under uncertainty (see e.g. Pindyck 1991, Chavas 1994, and Dixit and Pindyck 1994). In recent theoretical work the notions of irreversibility and adjustment costs have also been combined (Abel and Eberly 1994). But little has been done on combining the notions of irreversibility and adjustment costs in empirical work. In particular, we still lack empirical applications of investment rules estimated from models that allow for investment delays driven up by generalized adjustment costs, by uncertainty, or by both of them. Therefore, it is important to address these frictions delaying and spreading firm investments in a detailed empirical model.

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The frictions caused by uncertainty, irreversibility, and adjustment costs are of great importance, particularly in the Finnish hog industry which is facing a relatively drastic structural change. Investment frictions, if they exist, delay and spread investment over time. More importantly, they create entry barriers and protection by conferring cost advantages for early entrants and investors (see e.g., Tirole, 1992). The frictions will, therefore, have considerable implications for the success and survival of the Finnish hog industry as a new entrant in the Common Market.

We may expect that irreversibility and adjustment costs play a crucial role in the farmers' optimal response to the increased competition. Thus, they have important implications for our understanding of pork producers' decisions to invest or to exit the industry. They also help in understanding the adjustment process at the industry level and in designing structural adjustment programs[2], especially if the goal is to stimulate investments to get larger and more competitive production units for meeting domestic production goals. At present, however, we lack accurate information about the extent of irreversibility and the characteristics of adjustment costs in the Finnish hog farms. This study is designated to help close this gap in knowledge.

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2 Structural adjustment programs refer here to (public) programs that are applied to reduce negative short-term effects to promote the realization of desired long-term effects of a certain policy change.

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1.2 Objective and Scope of the Study

High production costs and relatively small herd sizes in the Finnish hog industry raise important questions concerning the future of the industry in the Common Market. First, is it realistic to expect that average hog production costs can be reduced fast enough, and far enough, to allow the Finnish hog industry to compete in the Common Market after a five year transitional period? Second, how much expansion in farm size will be needed in order to reduce average costs to competitive levels? Third, what is the most efficient path for farm expansion from the perspective of farmer welfare, and the welfare of society as whole? The answers to these questions require detailed knowledge of the dynamic structure of production, investment, capital accumulation, and costs in the Finnish hog industry.

This study analyses the dynamic structure of the Finnish hog industry to better understand how farm investments are determined and adjusted to external shocks. Knowledge of the dynamic structure of the industry will provide information about the hog industry's potential to adjust to the Common Market, and how adjustment programs might be designed for assisting the optimal adjustment.

As part of the structural analysis we investigate several specific questions surrounding the structure of the hog industry. Each of the following questions will be addressed in the remainder of the dissertation:

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1. Are there long run economies of size in the industry? The answer to this question provides information on the industry's potential to survive in the long run as part of the Common Market. If such size economies do not exist then expanding farm size is not going to reduce costs no matter how long the transition period is. Alternatively, if size economies exist then the industry has potential for reducing its production costs by expanding firm size. In this case the realized cost reductions will depend on the short run adjustment costs, too.

2. Are investments and expansion paths influenced by adjustment costs and do the shadow prices of installed capital differ from zero? The answers to these questions have important implications for the speed of adjustment and the length of time that it will take the industry to adjust to the shock of joining the Common Market.

3. If adjustment costs exist, how are they characterized? For example, are they increasing or decreasing in the scale of investment? If there are economies of scale in investments in the sense that adjustment costs increase at a decreasing rate or decrease in the scale of investment, then it may be appropriate to encourage swift, drastic one-time investment and a large scale adjustment in response to the shock of joining the Common market. But if there are diseconomies of scale in investment, such that adjustment costs increase at an increasing rate in the scale of investment, then it may be better to allow slow, incremental adjustment.

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4. Have hog farmer investments and access to capital been restricted by liquidity constraints? If farmer access to credit is restricted, or liquidity constraints are restricting investment for other reasons, then liquidity constraints may have important implications on how the sector can respond to the shock of joining the Common Market. The optimal adjustment may be influenced by these constraints.

5. What are the estimated shadow prices for capital and labor in the hog sector? These estimated shadow prices will indicate the marginal impact on production costs from adjusting capital and labor towards their steady state values. Thus, the shadow prices provide an indication of potential cost reductions from eliminating any discrepancy between the firm's desired (steady state) and current capital stock and labor allocation.

6. How do the steady state levels of capital stocks and labor services relate to their current levels? If there are no discrepancies between the steady states and current levels then neither adjustment costs, external restrictions (e.g. past production controls), nor the prospect of entry into the Common Market will have caused serious deviations away from steady state paths of capital and labor in the hog industry. But if there exists wide discrepancies between the steady states and current levels we need to know how long it will take to adjust to the steady state, and what policies might assist this adjustment process.

7. How are firms' capital and labor markets linked? To understand the adjustment process, it is essential to know how a discrepancy between the current and steady states of one input will affect the demand for other inputs and, hence, the whole adjustment process. Having knowledge on the linkages between the demands for individual inputs, and discrepancies between their current and steady states, it is possible to design adjustment programs with desired effects.

8. How do capital investments and labor services respond to changes in factor prices and output? As Finland entered the Common Market factor prices changed and production controls were abolished, which results in output adjustments. To understand the consequences of these changes we need to have detailed knowledge of input demand elasticities for factors of production in the sector.

9. How does uncertainty affect investments? It is valuable to know if, for example, uncertainty over policy makers own actions influence how adjustment programs affect farm investments and, hence, the whole adjustment process.

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Chapter 6

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1.3 An Overview

The study examines the dynamic structure of Finnish hog farms[3]. The goal is to answer the questions highlighted above by investigating the importance and consequences of uncertainty, irreversibility, and adjustment costs in hog producers' optimal employment and investment rules. First we develop a method for estimating a generalized model of investment which is consistent with the dynamic theory of the firm. Irreversible investment behavior is allowed to arise either from generalized adjustment costs, from uncertainty, or from both of them. The model is estimated for a group of Finnish hog farms using data from the period 1977-93, and the estimated investment and employment rules are used for addressing the questions given in previous section.

The study is organized as follows. Chapter 2 summarizes the current situation and outlook for the Finnish hog sector. Chapter 3 reviews and discusses the literature on methods for constructing dynamic investment models, and it concludes with a preferred method for our application. Chapter 4 sketches out the derivation of the economic model for the firms' dynamic optimization problem. This chapter concludes with the optimal decision rules. The next chapter constructs the statistical model for estimating the decision rules and concludes with the likelihood function used for estimating the model. Chapter 6 illustrates how the data are obtained and characterizes basic statistical properties of the data. The estimation results are presented in Chapter 7. Economic

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[3] The sample consists of farm level data on Finnish bookkeeping hog farms (about 100 farms a year) over the period 1976-1993. The data are described in detail in Chapter 6.

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implications of these results are discussed in Chapter 8. Finally, Chapter 9 provides a summary of the study and the most important conclusions, as well as some suggestions for future research.

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Chapter 2

THE HOG PRODUCTION SECTOR IN FINLAND

This Chapter reviews the current situation and outlook of the Finnish hog industry. We begin with a brief summary of the scale of the Finnish hog sector and, then, move on to industry structure. The structure of the Finnish hog sector is compared to that of the Danish hog sector. Denmark was chosen as a comparison, because it is an old EU member with one of the most competitive hog sectors among the EU member states (see, for example, Agra Europe, Nov. 1996). Denmark exports pork to other EU countries, including Finland.

Production costs are reviewed in the third section. The Finnish data are compared again to the Danish data to highlight the differences between small and large production units. The last section discusses the major changes in the economic environment facing Finnish hog farmers at the time Finland entered the EU. This discussion is focused on the factors that are driving the Finnish hog industry into a relatively fast (compared to the pre-membership period) structural adjustment phase. In particular, challenges and investment incentives provided by the new adjustment programs are introduced. The chapter concludes with some preliminary observations on how farmers are responding to the chang

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the changed environment even though it is too early to make final conclusions about farmer reactions.[1]

2.1 Size of the Hog Sector in Finland

Finnish agriculture is dominated by livestock production. When the size of the sector is measured by gross returns, hog production is the third largest livestock production sector, behind the milk and beef sectors. For example, in 1995 the gross returns from hog production accounted for 14 % of the total agricultural gross returns. The domestic hog industry also has an important impact on field crop production because it creates demand for feed grains, including barley and oats. Hog production is concentrated in the southern and western parts of Finland which are the most fertile and climatically favorable agricultural areas in the country.

In 1995 the number of hog farms in Finland was estimated at 6,200. About 2,600 of the hog farms were specialized in producing weaners and 2,200 of the hog farms were specialized in fattening pigs. The percentage of total farms that raise hogs was estimated at 3.7 % in 1995. Even though a relatively small percentage of farms raise hogs, the hog farms are very important, particularly in the southwestern part of the country where the share of hog farms out of all farms exceeds 10 %.

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[1] Main Sources in the Chapter: Official Statistics of Finland 1996: Farm Register 1995; Agriculture and Forestry 1996:2; and Monthly Review of Agricultural Statistics 1996.

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Total pork production in Finland has varied between 168-187 million kilograms in the 1990s whereas consumption has been less than production (Table 2.1). The consumption of pork has varied in the 1990s between 150 and 170 million kilograms (30-34 kilograms per capita). Prior to 1995 Finland was usually a net exporter of pork and very little pork was imported. These exports were, however, subsidized whereas imports were restricted by border controls. In 1995 imports grew considerably, because border controls were abolished and the decreased prices increased the amount of pork consumed. At the same time exports of pork decreased and Finland became a net importer of pork.

Most recently, the decreased retail prices of pork have increased pork consumption and turned the past net export situation into one in which consumption and domestic production of pork are roughly equal. Therefore, it is justified under the European Common Agricultural Policy, to have a goal of keeping the domestic pork production capacity at its current level so as to meet domestic demand for pork.

Table 2.1 Production, Consumption, and Trade Flows of Pork in Finland. [a]

	Year				
	1980	1990	1994	1995	1996
Production	169	187	171	169	172
Consumption	142	164	151	170	170
Exports	15	23	22	9	15
Imports	-	-	2	12	11

[a] Million kilograms per year.

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2.2 Farm Structure

After the second world war, farm size was already increasing in other parts of Europe but decreasing in Finland where the largest farms were divided to provide land for war veterans, and for those who had their farms in the lost eastern area. Since then, agricultural policies have supported farm income on small farms so that the average farm size has been increasing slowly. On average, Finnish farms are still small despite rapid technical changes that favor increasing farm size. In 1995 the average farm size was 22 hectares of arable land and 49 hectares of forest.

Farm expansion may also have been restricted by liquidity constraints caused by credit rationing. Until 1985 the Finnish credit market was rationed so that interest rates for loans were set below market clearing rates by the Bank of Finland. At these loan rates there was excess demand for loans, and firms' access to credit may have been rationed by restricted credit approvals. Credit market liberalization began in 1985 (for more details see e.g. Pajuoja 1995). In addition, farm growth has been partially deterred by the small supply of supplementary land. The supply of farm land has been further decreased by policies that included an incentive for retiring farmers to idle their land.

Also, the livestock production units are small on average because capacity expansions have been restricted through various production controls since the early eighties. Production controls were seen as an effective means of supporting high domestic producer prices and farm income. In the hog industry, authorities started to regulate the establishment of production units in 1975 by a licensing scheme, originally to prevent production from becoming too industrialized. The policy required the farmer to have a license for enlargening his existing facility or investing in a new plant. Specific criteria for new licenses have been complicated and they have varied over time, but the standard has been that licenses are granted only to full time farmers. In 1978 the licensing scheme was complemented by a rule that a farm has to have land for producing at least 25 % of the feed for the hog production. Until 1982 the maximum size of a new production unit was a fattening capacity of 1,000 pigs and, in practice, the scheme did not restrict investments. In the 1970s, for example, the license was granted to 91 % of all applications, and a notable number of applications were rejected only after the feed production restriction was implemented in 1978 (Kola 1987).

Nevertheless, the rules of the licensing scheme were tightened considerably in 1982. Thereafter, the standard has been that new licenses have not been granted to enterprises with over 400 hogs. Environmental regulations were also tightened. The license for new hog production capacity was granted only if the farm had enough land for producing at least two fifths of the feed needed in the hog production. This requirement was further increased in 1984 so that the farm had to have land for producing at least 75 percent of the feed needed in the hog production.

In 1995, when these stringent production controls were abolished, a new Agri-Environmental Program (AEP) was introduced. It provides incentives for farmers to keep the number of livestock units per hectare low for environmentally friendly utilization of manure and slurry. Therefore, the maximum size of a hog production facility is still in practice tied to the farm's arable land area. A farmer is eligible under the AEP only if he has

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has a maximum of 11 fattening pigs or three sows per hectare of land. A production unit of 60 sows and fattening capacity of 500 pigs, for example, is eligible under the AEP only if it has at least 66 hectares of arable land for spreading manure and slurry.

Even though the production controls did not significantly restrict the hog sector prior to 1982, the current hog industry in Finland is dominated by small family farms rather than by large industrialized units. In 1995 the average herd size of fattening pigs in Finland was 79, whereas an average Danish herd had 178 fattening pigs. That is, Danish herds were more than twice as large as Finnish herds. The average sow herd size was 31 sows in Finland, but in Denmark the average size was 75 sows, which is again more than twice as large as in Finland.

By comparing the production of different herd sizes, we find that Danish hog production is concentrated in much larger herds than Finnish production. Tables 2.2 and 2.3 present the distribution of sows and fattening pigs into different herd size categories for approximating and characterizing this concentration. In Denmark, for example, 76 % of sows are in production units of more than 100 sows. But in Finland only 2 % of herds and 9 % of sows are in herds of more than 100 sows. Also in finished hog production, the distribution of the farm size differs substantially between the two countries. In Denmark, for example, 43 % of fattening pigs were in production units of more than 500 pigs. In Finland only 13 % of fattening pigs were in such large units. Further, if we take the sum of all pigs in the herd, then in Denmark 61 % of the pigs are in herds of more than 1,000 pigs, while only 2 % of all pigs were in such large units in Finland.

Table 2.2. Sows and Sow Herds by Herd Size in Finland and Denmark in 1995.[a]

Herd size	% of sows		% of herds	
	Finland	Denmark	Finland	Denmark
1-49	61.4	9.4	84.2	57.7
50-99	29.4	14.3	14.1	15.0
100-199	6.1	31.6	1.5	16.9
200-499	3.1	35.1	0.3	9.3
>500	0	9.6	0	1.0

[a] Sources: Danmarks Statistik: Agricultural Statistics 1995; and Official Statistics of Finland: Farm Register 1995.

Table 2.3. Fattening Pigs and Pig Herds by Herd Size in Finland and Denmark in 1995.[a]

Herd size	% of fattening pigs		% of herds	
	Finland	Denmark	Finland	Denmark
1-49	10.8	4.0	59.7	40.9
50-99	14.4	5.5	15.8	13.9
100-199	21.9	12.2	12.3	15.4
200-499	40.1	34.9	10.7	20.5
>500	12.8	43.4	1.4	9.3

[a] See Table 2.2.

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2.3. Production Costs

In Finnish bookkeeping hog farms, with an average fattening capacity of roughly 200 pigs, the production cost of pork, excluding labor cost, is estimated at 9.4 FInnish Marks per kilogram (FIM/kg) in 1995. By adding labor cost of 2.8 FIM/kg we end up with the total production cost of 12 FIM/kg. Equipment and buildings account for 14 % and 6.8 % of the total production costs. The estimated production costs, even if we exclude labor, have exceeded the average producer price for pork (8.1 FIM/kg) by about 14 %. Nevertheless, producers received direct income transfers that accounted for about 41 % of their total agricultural revenues. These income transfers, if they are compared to the scale of the farms' hog production, corresponded to a gross return of about 5.7 FIM/kg.[2]

In 1995 the average total production cost of pork among all hog farms in Denmark was estimated at 9.7 FIM/kg, i.e. about 19 % lower than in the Finnish bookkeeping farms (Agra Europe 8/1996). The Danish bookkeeping farms were even more efficient than all farms on average. For example, in the group of the largest bookkeeping hog farms, with more than 1,400 pig fattening capacity, the production cost of pork is estimated at 7.6 FIM/kg (for more details see Table 2.5). [3]

Because there are no adequate data on the group of large-scale hog farms in Finland, we use the Danish bookkeeping farm data for characterizing how the average production costs depend on the size of the enterprise. Tables 2.4 and 2.5 present the

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[2] Costs have been estimated using the data in AERI Working Papers 5/96.

[3] Exchange rate 1 Danish krone (DKK) =0.779 FIM has been used.

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production costs for two herd sizes in both sow and fattening pig herds. Note that in these tables the smaller production units represent herd sizes that are also common in Finland. The group averages suggest that there is a notable decrease in production costs per unit produced as we move from the small unit to the large unit. Both feed and labor costs (per unit produced), in particular, decrease with herd size. Equipment costs, on the other hand, increase with herd size. These observations suggest that as herd size has been growing firms have been substituting equipment for labor which, in turn, has resulted in advanced feeding technologies and decreased feed costs.

Table 2.4. Production Costs of Weaners on Danish Bookkeeping Farms. [a]

Input	Herd size, number of sows		Difference %
	10-49	>250	
Feed	156	115	-26
Equipment	19.5	27.6	+42
Buildings	27.3	17.4	-36
Others	45.9	42.1	-8
Total costs excl. labor	249	202	-19
Labor	114	46.9	-59
Total costs	363	249	-31

[a] FIM/weaner. 1 DKK=0.779 FIM. Data Source: Økonomien i landbrugets driftsgrene 1994/1995.

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Table 2.5. Production Costs of Pork on Danish Bookkeeping Farms. [a]

Input	Herd size, number of fattening pigs		Difference %
	200-499	>1400	
Weaner	3.70	3.70	0
Feed	2.80	2.62	-6,4
Equipment	0.249	0.263	+5.6
Buildings	0.323	0.263	-19
Others	0.377	0.354	-6.1
Total costs excl. labor	7.45	7.20	-3.4
Labor	0.970	0.400	-59
Total costs	8.42	7.60	-17

[a] FIM/kg. 1 DKK=0.779 FIM. A 78 kg carcass weight has been used. Data Source: Økonomien i landbrugets driftsgrene 1994/1995.

It is likely, however, that the differences between the group averages in Tables 2.4 and 2.5 are affected by significant selectivity bias, because farmers have been allowed to choose their firm size endogenously in Denmark. Farmers who have been able to profit from large units have expanded firm size, while others have continued with smaller units. The selectivity bias is also supported by the observation that the number of weaners per sow increases with the herd size. In the large herds the number of weaners was 21.1 per sow, but in the small herds it was only 16.5 weaners per sow. Also, large units may have had more incentives to invest in animal breeding than small units, contributing to an increased number of weaners per sow as well as decreased feed costs per kilogram of pork produced in large units.

Nevertheless, the data suggest that most Finnish hog farms are too small to use modern production technology as efficiently as their Danish competitors. Therefore, we can expect that the Finnish hog industry has the potential to reduce production costs substantially through expanding firm size. Once firm sizes have increased (and average costs declined) sufficiently it may even eventually turn out that the industry can become competitive enough to export and expand market share outside Finland. Nevertheless, this is unlikely to happen at least in the short run. Furthermore, the domestic adjustment programs, including income transfers and investment subsidies, can no longer be justified under the Common Agricultural Policy if the industry goal is to penetrate to the export market. As explained above, the adjustment programs can only be justified to get the industry competitive enough for meeting domestic demand for pork and for maintaining the current meat processing industries in Finland.

2.4 Entry to the EU and Adjustment Programs

As noted above, the average producer price of pork fell by about 50 percent when Finland joined the EU. However, EU membership also resulted in a decrease in hog production costs as grain prices went down, environmental taxes on phosphorus and nitrogen used in fertilizers were abolished, and the European Value Added Tax (VAT) was introduced.

The projected income losses caused by the decreased producer prices are compensated for farmers through direct income transfers, which are: Common Agricultural Policy (CAP) reform aid, Less Favored Areas aid (LFA), agri-environmental aid, and national aid. National aid includes permanent Northern aid as well as a gradually declining aid for 1995-1999. The Accession Treaty did not allow for a sufficient permanent national aid in Southern Finland and, therefore, the introduced aid level would have declined very rapidly without any further stipulations. However, it was agreed that, if serious difficulties appear, a new form of national aid can be negotiated for Southern Finland as well. This so-called aid for serious difficulties, was negotiated in 1996 and is to be paid over the period 1997-1999. Even though numerous new direct income transfers were introduced, most farmers have to respond and adjust their production to the increased competition if they want to maintain an adequate income level (Ministry of Agriculture and Forestry 1996).

Hog producers' economic environment also changed because the licensing scheme, which earlier deterred farmers from expanding their production units, was abolished and new favorable adjustment programs were introduced. The main goal of these adjustment programs is to promote the structural adjustment of rural enterprises and rural areas into the European Common Market and Common Agricultural Policy (Ministry of Agriculture and Forestry 1996). Many other aspects have also been incorporated into the programs. For example, they provide incentives and impose restrictions on maintaining and improving environmental sustainability of agricultural production practices. More importantly, at least from the viewpoint of the present study, the program includes extensive investment and early retirement schemes which provide interesting alternatives for a farmer. He can either continue producing as before, and perhaps accept a gradually decreasing income level. Or he can quit farming and choose the early retirement plan provided he is old enough and eligible in the plan, or he can apply for investment subsidies and expand.

Finland got permission from the EU to support investments in hog production facilities temporarily during the transitional period of 1995-1999, provided the subsidy does not increase the total hog production capacity in Finland from the 1994 level. It is, therefore, required that at least the same amount of capacity has to exit the industry as new capacity is built. It was also required that certain standards for enterprise sizes are followed. These standards are reported in Table 2.6. Only full time farmers are eligible under the program.[4]

Table 2.6. Capacity Restrictions on Subsidized Hog Production Facilities. [a]

Type of investment	Minimum capacity	Maximum capacity
Enlargement of a facility for		
sows	50	400
fattening pigs	300	3000
A new facility for		
sows	65	400
fattening pigs	400	3000

[a] Source: Ministry of Agriculture 1996.

Nevertheless, the final terms and implementation of the investment subsidy scheme were delayed until 1996 and, in Southern Finland, the subsidy was further increased in 1997 as part of the serious difficulties aid package. Also, the time period over which the

[4] Requirements for a full time farmer: at least 50 % of the applicant's labor input used on the farm, at least 25 % of the income is from agriculture, and at least 50 % of the income is from the farm.

subsidies are allowed to be paid, was extended to the year 2001, because the implementation of the scheme was delayed (a summary of the key events concerning entry and adjustment to the EU is given in Table 2.7). The resulting maximum accepted subsidy rates, measured as percentages from the initial investment outlay, are presented in Table 2.8. The amount of the subsidy for an investment project is computed as a sum of the investment allowance and the present value of the interest rate subsidy. A 50 % subsidy may, for example, consist of an allowance that is 30 % of the investment outlay and an interest subsidized loan in which the discounted present value of the interest rate subsidy is 20 % relative to the investment outlay.

Table 2.7 Milestones of Finnish Agriculture in its Adjustment to the EU.

Year	Event
1991	Debate about Finland joining the EU began
1994	Accession Treaty was negotiated
1995	Finland joined the EU; a five year transitional period for agriculture began
1996	So-called aid for serious difficulties was negotiated
1997	Investment programs in effect (the package of serious difficulties and other investment subsidies)
1999	Last year of the initially negotiated transitional period
2001	Last year of the investment subsidies in the "serious difficulties" subsidy package negotiated in 1996

Table 2.8. Maximum Investment Subsidy Rates (%) from the Investment Outlay. [a]

Investment good	Southern Finland	Northern Finland
Production building for pigs [b]	50	27
Arable land	20	20
Drainage	50	20
Grain dryer	60	20
Storage [c]	40	20
Housing and heating	20	20

[a] Source: Ministry of Agriculture 1996.
[b] Either enlargement or a new facility.
[c] Storage for feed, machinery or farm products.

It has to be emphasized that the reported subsidy values only set a ceiling for the subsidy rates. The realized subsidies, as well as the types of investments subsidized, will depend on how many farmers apply for them and the amount of funds designated to the program. It may eventually turn out, for example, that the state budget for agriculture is too small to pay the maximum support rates, at least for all types of investments listed in the subsidy scheme.

Preliminary data suggest that the temporary investment subsidy scheme, with the risk that it will run out of sufficient funding, combined with a downward sloping trend (per capacity unit) in the direct income subsidy scheme, is accelerating investments in the hog industry, even though market prices are more uncertain than before. Farmers are responding not only to the incentives provided through the extensive investment programs but also to the expected lost direct income subsidies caused by delays in investment decisions. In other words, the value of information about market price movements has been smaller than the expected lost subsidies from postponing investments and, therefore, it has payed to take advantage of the highest subsidies rather than wait for new market information.

Investments in new production facilities started to emerge in 1995 and 1996. A survey made in spring 1996 indicates that 11% of hog farms had already invested in hog production facilities in 1995 or in early 1996. As suggested by the decreasing trend of the income subsidies, farmers in the southern support areas have been more eager than farmers in the northern areas to invest early (Kallinen et al. 1996).

The survey of Kallinen et al. (1996) also shows that only 5 % of hog farms plan to exit the industry within two years, while 70 % of the farms plan to continue in the industry after the year 2000. About 56 % of the farms staying in the business plan to invest in their hog production facilities and estimate their new production capacity at 1.6 times the current capacity. The majority of these investments will be realized between 1996 and 1998, and half of these investments have already begun.

Chapter 3

A REVIEW OF DYNAMIC INVESTMENT MODELS

This chapter reviews and discusses the literature on methods for constructing dynamic investment models. We start the review with the empirically tractable and widely used add hoc flexible accelerator model, because it provides a good framework for defining the central concepts and issues we are dealing with in our study. The next section highlights the most important literature on formulating dynamic optimization models that formally rationalize the theory of investment, i.e. the link between the theory of the firm and the flexible accelerator model. The chapter closes with a preferred approach for our study.

3.1 Flexible Accelerator

In the flexible accelerator model, a firm's capital stock is assumed to accumulate as a linear function of the firm's desired steady state capital stock and its actual, less volatile capital stock (Lucas 1967, Treadway 1971, and Mortensen 1973). In particular, a firm's net investment, $\dot{K}$, is proportional to the discrepancy between the firm's desired and actual capital stock such that

$$\dot{K} = N(K - \bar{K}),$$

$$\begin{aligned} \textit{where } N &= \textit{matrix of adjustment rates} \\ &\quad (\textit{the adjustment matrix}) \\ K &= \textit{actual capital stock} \\ \bar{K} &= \textit{desired, steady state capital stock} \end{aligned} \qquad \textbf{(3.1)}$$

Without any innovations or shocks to the system, the capital stock converges into a stable steady state level, provided that the characteristic roots of the adjustment matrix, N, lie between zero and one. Usually, the diagonal elements of N are expected to lie between zero and one, although this is a stronger requirement than the stabity condition.

Adjustment rates are symmetric if N is symmetric. With symmetric adjustment rates, a disequilibrium in the market of good s has the same effect on the investment of good j as a disequilibrium in the market of good j has on the investment of good s. Adjustment rates are independent if the off-diagonal elements of N are zeros, i.e. N is a diagonal matrix. Further, the capital stock adjusts instantaneously if N is an identity matrix. If, for example, the off-diagonal elements in the j^{th} row of N are zeros, and the j^{th} diagonal element is one, good j adjusts instantaneously to the changes in its steady state stock. A good that adjusts instantaneously is a variable input. A good which does not adjust instantaneously has been defined in the literature as a quasi-fixed input. We use the terms capital good, capital stock, and quasi-fixed input interchangeably.

Adjustment rates also can be asymmetric with respect to investment. In this case, an adjustment rate with a negative investment differs from that with a positive investment.

Modeling adjustment rates that are asymmetric in investment requires that the regimes of negative and positive investments can be identified in the sample.

A problem with the accelerator model is that it does not explicitly determine what the steady state capital stock is. In other words, the right hand side variable $\bar{K}$ is unobserved in (3.1) or, more importantly, a function that determines $\bar{K}$ is not defined by (3.1). The steady state capital stock has to be determined by another model and, therefore, the accelerator does not provide a rigorous theory of investment.

3.2 Dynamic Optimization Models

A formal investment theory, which is consistent with the theory of the firm, requires that we solve a dynamic multi-period optimization problem. The solution will then trace out an optimal investment demand as a function of exogenous state variables, including the firm's actual capital stock. Further, by setting net investment to zero the model can be solved for the optimal steady state capital stock, which is also a function of the exogenous state variables (excluding the firm's actual capital stock) in the model. Usually the dynamic optimization problems have been constructed so that the firm's one-period outcomes are linked to each other through frictions, modeled as uncertainty and/or adjustment costs.

There exists an extensive literature on investment under adjustment costs and investment under uncertainty. We highlight only the most important literature which is relevant to this study. Meese (1980) provides a comprehensive list of references on the adjustment cost literature prior to 1980, and Dixit and Pindyck (1994) and Pindyck (1991) have provided comprehensive reviews on investments under uncertainty and, in particular, the real options approach to irreversible investment.

The core problem in constructing dynamic optimization models of investment has been summarized by Keane and Wolpin (1994):

"*There are no conceptual problems in implementing models with large choice sets, large state spaces, and serial dependencies in unobservables. The problem is in implementing interesting economic models that are computationally tractable.*"

The literature on modeling adjustment costs in a dynamic context under uncertain future cash flows can be divided into four distinct strategies, or approaches. The first approach imposes restrictions on how expectations are formed, assumes an analytically convenient production technology, and solves for the optimal decision rules explicitly in a closed form. The second approach is more realistic than the first one, in the sense that it allows for both flexible production technology and flexible expectations structures by estimating the first order conditions (Euler equations) from a dynamic optimization problem directly. In the third approach, the entrepreneur's choice alternatives, as well as the space of the state variables, are discretized and the optimization problem is then solved numerically without solving for any first order conditions or closed form decision rules. Each of these three approaches are primal, in the sense that they involve explicit solution of a well-defined optimization problem. The fourth approach imposes a structure on how expectations are formed, allows for flexible production technology, and uses intertemporal duality for deriving the closed form optimal decision rules.

The primal and the dual models are both functions of prices and possibly some exogenous constraints, like exogenous technology and output (Howard and Shumway 1988). But the specifications of these models differ. The primal model is specified in terms of the instantaneous (or one-period) production function, cost function, or profit function. Then, the necessary optimality conditions are imposed through a set of first order conditions (Euler equations) or, alternatively, the model is solved numerically. In the dual model, on the other hand, the optimal value function is specified and the envelope theorem is used to derive the decision rules. In subsequent sections we shall examine the primal approach and the dual approach in more detail.

3.2.1 Primal Approach

The first primal method considered here was developed by Hansen and Sargent (1980,1981), and further modified by Epstein and Yatchew (1985). The approach is to define an analytically convenient functional form for the one-period cost, production or profit function, and to solve the decision rules explicitly in a closed form through the Euler equations. Then the observed decision variables are used for estimating either the structural form parameters or the reduced form parameters. In this approach, information from the transversality conditions can be incorporated into the estimation equations for increasing the efficiency of the estimates, but at the cost of restricting the production technology to be quadratic. Perhaps more importantly, a difficulty arises in a multiple capital good setting if the adjustment rates are dependent across the capital goods, i.e. the adjustment matrix is not diagonal. With a nondiagonal adjustment matrix, it is not generally possible to find explicit expressions for the reduced form parameters in terms of the underlying technology parameters (structural form parameters). If the number of capital goods exceeds two, one has to assume and impose independent adjustment rates in order to get a formal link between the reduced form parameters and structural form parameters. That is, the adjustment matrix has to be diagonal.

The difficulty with the closed form solutions is, in particular, that the adjustment matrix, which solves the characteristic equations corresponding to the Euler equations, is related in a complex fashion to the structural form parameters, say, to the parameters in the production function. Epstein and Yatchew (1985) avoid this problem by reparametrizing some of the structural form parameters so that they are functions of the adjustment matrix and the remaining structural form parameters. Even though the reparametrization technique can be used to establish a feasible link, at least in some special cases, between the structural and reduced form parameters, the algebraic relationship between the parameters remains ambiguous and complex.

The second approach considered here has been developed by Kennan (1979), Hansen (1982), and Hansen and Singleton (1982), and applied, for example, by Pindyck and Rotemberg (1983). In this approach, the structural form parameters are estimated directly from the Euler equations without solving them for closed form decision rules. Future exogenous variables are replaced by their observed values and, then, an instrumental variables technique is used to estimate their expectations. Kennan (1979), for example, suggests a simple two-step least squares procedure for obtaining consistent parameter estimates. Hansen and Singleton (1982), on the other hand, construct a set of population orthogonality conditions from the Euler equations and estimate their sample counterparts by the Generalized Method of Moments (GMM) estimation technique. Under rational expectations and fairly weak assumptions about the stochastic data generating processes, the method generates consistent estimates for the structural form parameters. Because the method circumvents solving the Euler equations for the optimal decision rules, it is very flexible in terms of allowing a wide range of alternative non-quadratic production technologies. However, the information included in the transversality conditions is ignored and the resulting estimates are not necessarily efficient (Epstein and Yatchew 1985, and Prucha and Nadiri 1986). But, more importantly, this approach generally cannot be used to compute price or output elasticities, because the optimization problem has not been solved for the decision rules (e.g. Thjissen 1996).

Later, Rust (1987) developed a numerical method for estimating a full solution to a structural, discrete choice dynamic programming model without solving it for optimal decision rules or any necessary first order conditions. He used the maximum likelihood estimation technique and a "nested fixed point algorithm" to iterate Bellman's equation until convergence occurred inside each iteration of the likelihood function. Although we can take advantage of particular structures, functional forms, or distributional assumptions, as he did, the method will be limited by computational complexity. Therefore, it is expected that this method will not be feasible for a large dimensional problem. For example, the original Rust (1987) bus engine replacement application had only two alternative choices (replace or continue), one observed state variable (mileage), and homogenous data (similar buses). And still all of his cost function specifications did not converge.

More recently, some simulation and approximation methods, which circumvent the need for an exact full solution to the optimization problem, have been developed (Stock and Wise 1990, Keane and Wolpin 1994, Stern 1994). They allow for more complex dynamic programming models to be estimated feasibly, but require that the state variables are discretized so as to reduce the number of elements in the state space. The simulation methods can be used to approximate sequential dynamic discrete choice decisions with mutually exclusive alternatives, especially when the state space is not large. The computational burden comes from the fact that to obtain the alternative specific value functions we must compute the expected maximum of the future period rewards (or costs) for each alternative. If one desires an exact solution, the expected maximum functions involve multiple integrations with as many dimensions as we have choice-alternatives in the model. The computational intensity is further increased because the resulting expected maximum functions must be evaluated at each element of the state space for tracing out the optimal choices. The computational burden could be reduced by the method for approximating the expected maximum functions as suggested by Keane and Wolpin (1994). Although the proposed method performed well in the study of Keane and Wolpin (1994), they conclude: "*Much additional work must be done to determine the method's general applicability*".

3.2.2 Dual Approach

The dual approach is based on dynamic, intertemporal duality theory, established by McLaren and Cooper (1980), formalized by Epstein (1981), and further explored by Epstein and Denny (1983). The method has been extensively applied to the dynamic investment and capital accumulation problems in the late 1980s and early 1990s. In a typical dual approach, a risk neutral entrepreneur is assumed to minimize an expected value of a discounted sequence of production costs conditional on exogenous input prices and output levels. A flexible functional form is then chosen for the optimal value function, and the optimal decision rules are derived by applying the envelope theorem directly to the value function.[1]

The dual approach is the most flexible in terms of the generality of the underlying production technology. In particular, a major advantage of the dual approach is that the

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[1] These kinds of applications are, for example, Taylor and Monson (1985), Shapiro (1986), Vasavada and Chambers (1986), Stefanou (1987, 1989), Howard and Shumway (1988, 1989), Weersink and Tauer 1989, Weersink 1990, Fernandez-Cornejo et al. (1992).

adjustment matrix and the parameters in the optimal value function are related to each other in a simple fashion and, therefore, it is straightforward to solve the model for closed form decision rules in terms of the underlying structural form parameters (Epstein and Denny 1983). Restrictions on the production technology, such as independent adjustment rates, are not required. Independence of adjustment rates can be tested rather than assumed. The model can be easily extended to cover an arbitrary number of variable inputs, capital goods, and outputs.

Although the dual approach is flexible with respect to the underlying production technology, it has limitations in identifying price and output expectations separately from the technology parameters (Taylor 1984). With endogenous output and an estimated supply equation, the model has enough overidentification restrictions for identifying and testing simple expectations structures that follow a first order differential equation system (Epstein and Denny 1983). But if an exogenous output is assumed and no supply equation is included in the model, there are no overidentification restrictions for testing how expectations are formed. Therefore, it has been a standard procedure that the technology parameters have been pinned down by imposing a specific expectations structure on the model.

Typically, studies have imposed static price and output expectations such that the current prices and outputs have been expected to prevail forever (e.g. Fernandez-Cornejo et al. 1992, Vasavada and Chambers 1986). Some authors, e.g. Vasavada and Chambers (1986), claim that static expectations are realistic in relatively small agricultural firms where goods can be stored easily and frequent acquisition of market information is costly.

In European agriculture, static expectations may be realistic because the marketing institutions and agricultural legislation have stabilized and protected farm outputs and farm gate prices (e.g. Thjissen 1994). Thjissen (1996) even concluded that the model with static expectations fits the Dutch dairy farm data well, but the rational expectations model is inconsistent with the theory.

In many duality applications, however, the seemingly restrictive assumptions on the expectations structure can be made without much loss of generality. The expectations assumption does not necessarily alter the most important behavioral economic results. The statistical inference concerning adjustment rates, as well as price and output elasticities, may be independent of the expectation structure as long as they meet the Markov property, in the sense that the probability distribution and expected value of the next period price (or output) is a function of current prices and output. The reason is that, under Markovian expectations, the behavioral equations are functions of current prices and outputs, which include all relevant information about their future values. Therefore, correctly specified behavioral equations will depict the aggregate effects of expectations and technology even though their separate effects cannot be identified and distinguished.[2]

Most dynamic duality models of investment and capital accumulation use aggregate data maintaining the assumption of interior solutions with positive gross investment. The assumption can be made without loss of generality only in aggregate data. Studies using firm level data, on the other hand, have typically used the primal approach based on the

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[2] The claim holds in our model, and this will become clear in the next chapter, where the economic model is derived.

argument that the dual approach is not applicable, because firm level investment can be zero, or even negative (e.g. Thjissen 1994). But there are no theoretical reasons that prevent relaxing the assumption of positive investments, and applying the dual approach to firm level data. Epstein (1981) concludes that the regularity conditions of the optimal value function with positive gross investment are readily extended to account for negative gross investment too. Nevertheless, it is difficult to construct an optimal value function such that the regularity conditions hold for all individual firms, because some of the regularity conditions differ qualitatively between the investing and disinvesting firms. For example, consistent shadow prices for installed capital, which are partial derivatives of the optimal value function, must alternate their signs depending whether the firm is investing or disinvesting (Epstein and Denny 1980).

Another alternative is to endogenously stratify the data into positive, zero, and negative investment regimes. One can then specify a consistent value function for each of these regimes, and the regularity conditions for a consistent value function can be tested within each regime. With this approach, the firm level data provide a good opportunity to account for the asymmetries and discrete characteristics in the optimal investment rules. The decision rules can be estimated, for example, by the maximum likelihood technique. Chang and Stefanou (1988) and Oude Lansink (1996) have exploited this idea by modeling positive and negative net investments using an endogenous dummy model, and the two-stage self-selection model of Heckman (1976). However, the dimensionality problem becomes severe when modeling both discrete and continuous characteristics of the optimal decision rules with a large number of capital goods.

3.3 Preferred Approach

Among the reviewed approaches, there are trade-offs in the flexibility of the underlying technology, identification of expectations, statistical efficiency, computational intensity, and the form of the results. The traditional primal methods with closed form decision rules would produce consistent results in a preferred form (e.g. elasticities), but these methods have problems. The derivation of the optimal decision rules is complex unless the production technology is restricted. If the number of capital goods exceeds two, the technology has to be restricted so that the adjustment matrix is diagonal. In addition, sufficient overidentification restrictions for testing how expectations are formed requires profit maximization conditions so that all the input demands, the output supplies, and equations on price processes can be used for identification (Epstein and Yatchew 1985). With exogenously determined output, the structure of expectations has to be imposed on the model without testing its validity.

If the Euler equations, on the other hand, are used for estimating the parameters we can allow for more flexible technology, but the closed form decision rules and elasticities can no longer be computed. Further, expectations could not be tested with this approach either, because the profit maximization conditions are not met in our application. The reason is the lack of overidentification restrictions, as explained above. Therefore, by using this method nothing would be gained compared to the dual approach, which allows flexible technology but has no overidentification restrictions for testing the expectations.

In this study, we use the dual approach because we wish to model more than just one quasi-fixed input and to test for independent adjustment rather than assume it. We are also interested in price, output, and scale elasticities, which are straightforward to estimate when the dual approach is used.

Our dual model is constructed so that the instantaneous production technology is augmented by internal adjustment costs, which has been the standard in the adjustment cost literature (e.g. Fernandez-Cornejo et al). But, in addition, we generalize the model to allow for uncertainty, irreversibility, and more general adjustment costs, like fixed adjustment costs. Therefore, the model allows not only for investment smoothing but also for an optimal choice of inaction, i.e. an optimal choice of zero investment[3].

The adjustment cost literature has focused only on the regime of positive gross investment, with few exceptions. Chang and Stefanou (1988) and Oude Lansink (1996), for example, stratified data into two regimes, contracting and expanding firms, while modeling adjustment costs asymmetric in net investment. But we follow Abel and Eberly (1994), stressing irreversibility of agricultural investments, and incorporate the mixture of discrete and continuous characteristics of investments by identifying and partitioning the following two investment regimes:

(i) a regime of zero gross investment and

(ii) a regime of positive gross investment.

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[3] An adjustment cost rationalization of Johnson's (1956) fixed asset theory, as in Hsu and Chang (1990), results in a similar identification of frictions and classification of observed investment demands.

The regime of negative gross investment was excluded in the analysis because the number of negative gross investments in the data was too small for a complete analysis. Changes in the labor services, on the other hand, did not include zeros and only the regimes of negative and positive changes in labor services were modeled. We now move on to a detailed derivation of the economic model.

Chapter 4

THE ECONOMIC MODEL

This chapter derives the economic model used in the study. We start by defining a general set-up for the economic model. That is, we describe how the stochastic processes are determined, how we deal with the optimal timing and size of investment, and how liquidity constraints are incorporated into the analysis. Then, we sketch out the main steps in dynamic optimization and deriving the optimal decision rules. The chapter concludes with a discussion of the optimal decision rules.

4.1 Stochastic Processes and their Expectations

The investment literature has revealed the significant effect that expectations and uncertainty have on investment decisions. Recent theoretical work has incorporated expectations and uncertainty into the analysis and used stochastic calculus to derive stochastic investment rules.

In dynamic models, as opposed to static models, uncertainty affects the necessary conditions for the optimum even when the optimizing agents are assumed to be risk neutral. Therefore, internal consistency in a dynamic model cannot be maintained by just solving a deterministic problem and then taking expectations and adding random shocks on the model. A theory of how expectations are formed and how stochastic processes are generated has to be incorporated explicitly into a dynamic model before deriving the necessary conditions for optimality.

One special method to account for expectations is to augment the optimal value function by a simplified measure of expectations, as in Howard and Shumway (1989). They modeled technology expectations by augmenting the optimal value function with a time trend. A detailed discussion on the method can be found in Larson (1989). A more widely used, and more general method, involves modeling expectations and uncertainty through stochastic transition equations for the exogenous state variables in the model.

For analytical convenience, most studies have maintained simplified assumptions about the stochastic processes which generate expectations and uncertainty in the transition equations. Ingersoll and Ross (1992), for example, allow for a stochastic discount factor, while Fousekis and Shortle (1995) model investment under stochastic depreciation. Stefanou (1987) derived investment rules under capital augmented technical change that evolved stochastically. But in most studies, uncertainty is assumed to be driven by prices and possibly by the level of an exogenous output.

We assume that the discount rate is known to the firm but that it is time-varying as in Sakellaris (1995). Uncertainty is driven by an exogenous output level and input prices that are stochastic, log-normally distributed, and follow a non-stationary geometric Brownian motion without drift. More specifically, these assumptions imply that changes in the output level and input prices are expected to be zero, and have log-normal distributions with independent increments. The output level and prices satisfy the Markov property so that their next period probability distributions are functions of their current stage only, and variance of the prediction error increases linearly with the time horizon (e.g. Hamilton 1994).

We begin by deriving the model allowing for a non-zero drift rate to show that the assumption of static expectations can be made without much loss of generality in our model. The logarithms of the prices and output are stacked into a vector Z, which follows a simple Brownian motion[1]:

$$
\begin{aligned}
\Delta Z &= \mu(Z)\Delta t + Pv, \\
\\
\textit{where } Z &= (lnY, lnW, lnQ)' = \textit{vector of exogenous state variables} \\
Y &= \textit{output vector} \\
W &= \textit{price vector for variable inputs} \\
Q &= \textit{rental price vector for capital goods} \\
\Delta Z &= \textit{change in } Z \\
\mu(.) &= \textit{a nonrandom function or a drift parameter} \\
P &= \textit{any matrix such that } \Sigma = PP' \\
\Sigma &= \textit{variance-covariance matrix with diagonal elements } \sigma_i^2 \\
v &= \textit{an i.i.d. vector with } E(v_t) = 0 \textit{ and } E(v_t v_t') = I\Delta t
\end{aligned}
\tag{4.1}
$$

It is implicit in our treatment that expectations are also rational, in the sense that they are based on (4.1). In Chapter 7 we examine the price and output series and conclude that (4.1) with zero drift rate can be regarded as a realistic assumption for this application, because it does not contradict the observed data series on prices, output, and rental rates of land for

[1] The time subscripts have been dropped to simplify notation.

Finnish hog farms. Under (4.1), the stochastic decision rules can be derived by using Ito's lemma as, for example, in Hertzler (1991).

4.2 Timing and Size of Investments

Irreversible investment decisions involve two components: the choice of timing and the choice of the investment size. Both the timing and size have to be chosen simultaneously. For example, a firm with a physical plant must decide when to pay the sunk cost of converting the existing facility into a new one, and how much capacity to build up in the new plant (Capozza and Li 1994). These kinds of decisions have been modeled in the literature as binary one-time decisions rather than continuous or incremental capacity replacements and expansions (e.g. McDonald and Siegel 1986). But the data available for our analysis, described in chapter 5 below, do not allow us to identify a binary one-time decision problem. For example, a building investment observed in the data may be a partial replacement and/or enlargement of the existing facility, or it can be a completely new plant. In addition, the investment expenditure may have been spread over several periods as a result of the adjustment costs that are increasing in investment. Therefore, we model investment as an incremental decision, but we allow for optimal choices of inaction, i.e. zero investments. But still, investment decisions are assumed to be made simultaneously. In other words, farmers decide simultaneously between the choices to take no action, or how much to invest.

The marginal condition for optimal disinvestment or investment does not hold at zero gross investment. It is optimal to choose zero investment if the shadow price of the installed capital is between the marginal revenue from disinvesting and the marginal cost of investing (including the cost of killing the investment option). In other words, if neither disinvestment nor investment would yield the highest expected discounted net returns, farmers will postpone investment decisions and choose zero gross investment. Hence, it is likely that the optimal investment rules have a corner solution at zero gross investment, primarily due to potential irreversibility.

The optimal size of an investment, on the other hand, is analyzed as an incremental decision. The marginal conditions for optimal investments are assumed to hold whenever gross investments differ from zero. In other words, at the optimal level of positive investment the shadow price of the installed capital equals the marginal cost of investing.

4.3 Intensity of Use and Depreciation

Use and decay characteristics of capital goods differ because the optimal intensity of use, or the optimal service extraction rate, is decided repeatedly once the good has been purchased and installed. In other words, the optimal extraction rates and decay patterns of capital goods vary over time, even if purchases themselves are lumpy and irreversible. Robison and Barry (1996) distinguish four groups of capital goods according to their decay characteristics and flexibility in use. We consider here two of them. They are (1) goods for which decay depends primarily on time, and (2) goods for which decay depends on both time and service extraction rates.

In our application, buildings and drainage (and land) fall into the first class of durables. They are worn out primarily by time and it is typical that the marginal costs of extracting services are low, or even zero. As long as marginal services have positive value, services are extracted from these durables at the full capacity. Therefore, we assume that services are extracted from buildings, drainage, and land at a fixed rate and they depreciate at a constant geometric rate. This assumption can be made without much loss of generality.

Machinery, on the other hand, falls clearly into the second class of durables so that its depreciation is a function of both time and intensity of use. Machinery wears out faster the higher the extraction rate is. The optimal extraction rates may vary over time with the actual decay so that the extraction rates for an aged machine differs from those of new machinery. The optimal extraction rates may be further influenced by output prices and input prices. Therefore, a fixed depreciation rate for machinery is a strong assumption that cannot be made without loss of generality. Nevertheless, with the data available for our analysis we cannot control for machinery's actual service extraction rates. Hence, we assume a constant geometric depreciation rate for machinery, i.e. that the service extraction rate of machinery is constant.

4.4 Liquidity Constraints

It may be claimed that farmers' access to credit has been rationed for two reasons. First, until 1985 the Finnish credit market was organized so that interest rates for loans were set below the market clearing rates. At these loan rates, there was excess demand for loans, and firms' access to credit may have been rationed by restricted credit approvals. Credit market liberalization began in 1985.

Second, farmer access to credit may have been rationed over the whole study period by asymmetric information, or by asymmetric payout and payoff of risky credit between the borrower and lender. As an extreme case, when a firm's survival is at stake, the firm has an incentive to increase borrowing as long as the lender approves funding (for more details, see Robison and Barry 1987). Because the firm's cash flows determine its ability to meet debt obligations, one can conjecture that the access to credit may have been rationed for firms with high liabilities relative to their gross returns.

For studying the effects of credit rationing we exogenously partition the sample into four partitions according to two factors: credit market regime and the firm's liabilities to gross returns ratio. In other words, the credit constraints are not formally imposed in our optimization problem and economic model, but we informally check whether the estimation results are robust to the changes in the credit regimes. Zeldes (1989) has used similar methods for studying liquidity constraints.

4.5 The Optimization Problem

The optimization problem could be stated and solved by two different techniques: contingent claims analysis or stochastic dynamic programming. In most applications, however, they both give identical decision rules, although they make different assumptions about discount rates and financial markets (Dixit and Pindyck 1994). In contingent claims analysis, the discount rate is a risk free rate by definition. In dynamic programming, on the other hand, the discount rate is exogenously given and cannot necessarily be interpreted as a risk free rate. Contingent claims analysis requires assumptions on the structure of financial markets for trading risks as a bridge for deriving the decision rules but the dynamic programming approach requires no such assumptions. Although the seemingly more restrictive assumptions of contingent claims analysis can be made without loss of generality, we chose here to use stochastic dynamic programming. For analytical convenience, a continuous time formulation is used. A discrete approximation is made later to fit the decision rules to the data. This approach is standard in dynamic dual models.

Risk neutral farmers are assumed to minimize a sequence of discounted production costs conditional on a set of state variables, which includes the current capital stock, output level, and input prices. We partition the set of the state variables into two vectors K and Z. The vector K is the capital stock controlled through gross investment I. The vector K also includes labor that is controlled through net changes in labor input $\dot{L}$. The vector Z was defined previously in (4.1). The optimal value function is defined as the minimum of discounted cost over the infinite future time horizon:

$$J(Z_0,K_0) = \min_I E_0 \left\{ \int_0^\infty e^{-rt} \{ C^\eta(W,Y,K,I) + (U+\gamma)Q'K \} \, dt \right\},$$

subject to (4.1)

$\Delta K = (I - \delta K)\Delta t$

Z_0, K_0 *given*

where **(4.2)**

K = *capital stock*

I = *gross investment*

E_t = *expectation conditioned on information at time t*

r = *discount rate*

C^η = *instantaneous variable cost function*

U = *identity matrix*

γ = *diagonal matrix of parameters*

δ = *diagonal matrix of constant depreciation rates*

The instantaneous variable cost function is defined as[2]:

$$C^\eta = \min_X \{ W'X: \; F(X,Y,K,I) = 0 \}$$

where

F = *transformation function with usual regularity conditions*

X = *demand for variable inputs*

The variable cost function, C^η, accounts for internal adjustment costs through the technology constraint *F(.)*=0. The transformation function is augmented by gross investment because, under the adjustment cost hypothesis, scarce resources need to be withdrawn from production

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[2] The regularity conditions on F(.) are usually stated as: F(.) is continuous, twice differentiable, and convex in I; Strictly increasing in Y; and strictly decreasing in X, K, and absolute value of I.

to install new capital stock (Lucas 1967). Therefore, even if production is increasing in the cap4ital stock it can be decreasing in gross investment. In turn, costs are increasing in investment at a given output level. Therefore, the solution to the instantaneous cost minimization problem is a function of both capital stock and gross investment. Variable costs are decreasing in the capital stock but increasing and convex in investment (Epstein and Denny 1983).

A wedge between purchase and sales prices of capital goods is captured by the diagonal parameter matrix γ, which is allowed to differ from zero only within the regime of negative investments or negative changes in the labor input. The sales price of a good is expected to be less than or equal to its purchase price (Arrow 1968). Therefore, we expect that $\gamma < 0, \textit{ for all } \Delta K < 0$. It will become clear from the optimal decision rules below that nonzero elements in γ imply adjustment rates which are asymmetric in investment.

4.6 Necessary Conditions for Optimality

To derive the necessary conditions for a minimum, we start with the principle of optimality and Bellman's equation, which has the following form at time t_0 (Kamien and Schwartz 1991)[3]:

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[3] All subsequent equations are subject to the constraints in (4.2) and the definition for C.

$$J(t_0,Z_0,K_0) = \min_I E_0 \left\{ \int_{t_0}^{t_0+\Delta t} C(Z,K,I,\gamma)\, dt \;+\; J(t_0+\Delta t, Z_0+\Delta Z, K_0+\Delta K) \right\}, \tag{4.3}$$

$$where\ C(Z,K,I,\gamma) = C^{\eta}(W,Y,K,I) + (U+\gamma)Q'K$$

Next, assume a constant control, I, for a small time period Δt, which implies a constant C over Δt. Then, the integral on the right-hand side of (4.3) equals the product (or area) $C\Delta t$. Further, expand $J(t_0 + \Delta t,\ Z_0 + \Delta Z)$ and use Ito's lemma, which results in:

$$J = \min_I E\left\{C\Delta t + J + J_t\Delta t + \nabla_Z J\Delta Z + \nabla_K J\Delta K + \frac{1}{2}(Pv)'(\nabla_Z^2 J)(Pv) + h.o.t.\right\},$$

$$\begin{aligned} where\quad J_t &= \partial J/\partial t \\ \nabla_Z J &= \textit{Gradient of } J \textit{ with respect to } Z \textit{ evaluated at } (t_0,Z_0,K_0) \\ \nabla_K J &= \textit{Gradient of } J \textit{ with respect to } K \textit{ evaluated at } (t_0,Z_0,K_0) \\ \nabla_Z^2 J &= \textit{Hessian of } J \textit{ with respect to } Z \textit{ evaluated at } (t_0,Z_0,K_0) \\ h.o.t &= \textit{Higher order terms which approach zero as } \Delta t \to 0 \end{aligned} \tag{4.4}$$

Subtracting J from both sides of (4.4), dividing the result through by Δt, and rearranging gives:

$$-J_t = \min_I E\left\{C + \nabla_Z J\frac{\Delta Z}{\Delta t} + \nabla_K J\frac{\Delta K}{\Delta t} + \frac{1}{2}(Pv)'(\nabla_Z^2 J)(Pv)\frac{1}{\Delta t}\right\}, \tag{4.5}$$

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where $-J_t = -\partial J / \partial t = rJ$. The left-hand side of (4.5) equals rJ, because the time variable t appears in J only through the discount factor e^{-rt}. Finally, take expectations and take the limit as $\Delta t \to 0$ to get the fundamental partial differential equation obeyed by the optimal value function [4]:

$$rJ = \min_I \left\{ C + \nabla_Z J \mu(Z) + \nabla_K J(I - \delta K) + \frac{1}{2}[Vec(\nabla_Z^2 J)]'[Vec(\Sigma)] \right\},$$

$$= \min_I \{ C + E[\partial J/\partial t] \} \qquad \textbf{(4.6)}$$

where

$$\Sigma = E[\varepsilon\varepsilon'] = PE[vv']P'\frac{1}{\Delta t} = PP'$$

$$= \textit{covariance matrix for the error terms in } (4.1)$$

Equation (4.6) is often referred to as the Hamilton-Jacobi-Bellman (HJB) equation. It states that the optimal value function equals the lowest discounted present value of the sum of four terms; (1) the immediate cost or payout; (2) the marginal cost from expected changes in output and prices, multiplied by the magnitude of the expected change in the output level and prices; (3) the marginal cost of the optimal change in the capital stock multiplied by the magnitude of the optimal change in the capital stock; and (4) a risk premium which is driven by the volatility of prices and output. The optimal value function is increasing with volatility of the output level and prices. The term $\nabla_K J$ is interpreted as a shadow price for installed

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[4] For some matrix $A=(a_1\ a_2\ ...\ a_3)$ the vec-operator stacks the columns, $a_1\ a_2\ ...\ a_3$, of A into a one column vector, $Vec(A)= (a_1'\ a_2'\ ...\ a_3')'$.

capital. It measures how many units the expected discounted present value of the firm's cost stream would change if the amount of installed capital in the firm is changed (ceteris paribus) by one unit.

Alternatively, the equilibrium model (4.6) can be interpreted per unit of time and the cost flow can be thought as a (negative) asset with value J. Then, the left hand side, rJ, is the threshold payout per unit of time, with a discount factor r, for a decision maker to be willing to hold the asset. On the right-hand side, the first term is the immediate payout. The expected rate of capital gain or loss consists of the second and the third term. In addition, a decision maker requires compensation for the risks of holding the asset. The risks are accounted for by the fourth term on the right-hand side. For example, the more volatile the prices and output level are, the lower immediate payout is required for a decision maker to hold the asset.

An optimal value function (J), which solves the minimization problem in (4.2), necessarily satisfies the second order differential equation (4.6). If, in addition, C is convex in (I,K), the sufficient conditions for a minimum are met (Kamien and Schwartz 1991). The convexity of C in (I,K) implies that J is convex in K. Nevertheless, convexity is not required by the necessary condition for a minimum in (4.2) and we can conclude that if the integral in (4.2) converges, the optimal decision rules exist and are unique.

It is expected, however, that the optimal investment pattern is discontinuous at zero investment, which generates kinks in the optimal path of K. The optimal value function (J) and the shadow price for installed capital ($\nabla_K J$) must, nonetheless, be continuous along the optimal path of K. The Euler equation is satisfied between the boundaries and, at the boundaries, the Weierstrass-Erdmann Corner Conditions must hold (Kamien and Schwartz 1991). Similar conditions are also called the "Value-matching and smooth-pasting conditions" for a free boundary optimization problem (Dixit and Pindyck 1994). These conditions imply that J and $\nabla_K J$ are continuous along the optimal path of K. As a special case, Abel and Eberly (1994) show that if the instantaneous cost function is homogenous of degree ρ in (K,I), then so is J. Therefore, we can conclude that, within the partition of I, certain differentiability conditions hold between J and C. The regularity conditions for J can be deduced from the regularity conditions for C.[5]

This result is important because it allows us to specify a consistent functional form for J and test the characteristics of C from J. Optimal value functions (J) which are consistent with the regularity conditions of C, assuming positive gross investments, are necessarily characterized by the following: [6]

(B.i) J is real valued and nonnegative.

(B.ii) $$(r+\delta)(\nabla_K J)' - (U+\gamma)Q - (\nabla_{ZK} J)\mu(Z) - (\nabla_K^2 J)\dot{K}^* - \frac{1}{2}\nabla_K\left[Vec(\nabla_Z^2 J)' Vec(\Sigma)\right]' < 0$$

---

5 The local dual relationship between the optimal value function and the instantaneous function has been proven by McLaren and Cooper (1980) and by Epstein (1981).

6 In the deterministic case with $\mu(Z)=0$, the differentiability conditions for positive gross investment are given in Epstein and Denny (1983). Condition (B.vi) follows, for example, Abel and Eberly (1994). A prime superscript, an asterisk, and a dot refer to the transpose, the optimal value, and the time derivative.

$(\nabla_K J)' < 0$

$$r(\nabla_Y J)' - (\nabla_{ZY} J)\mu(Z) - (\nabla_{KY} J)\dot{K}^* - \frac{1}{2}\nabla_Y\left[Vec(\nabla_Z^2 J)'Vec(\Sigma)\right]' > 0,$$

where $\dot{K}^*$ is given by (4.11) below

(B.iii) J is nondecreasing and concave in (W, Q).

(B.iv) Well defined optimal decision rules exist and take the form given in (4.11), i.e. the integral in (4.2) converges.

(B.v) The optimal decision rule $I^* = \dot{K}^* + \delta K$ defines a unique, globally stable steady state $\bar{K}(Y,W,Q)$ for capital stock.

(B.vi) J is positively linearly homogenous in prices (W, Q)

Property (B.i) is self-evident. Properties (B.ii) are obtained by differentiating (4.6) with respect to K, I and Y, rearranging, and using the properties of C. They are duals to $\nabla_K C^{\eta\prime} < 0$, $\nabla_I C' > 0$, and $\nabla_Y C' > 0$. Condition (B.iii) follows immediately, if C is convex in I and concave in W. By adding the conditions (B.iv) and (B.v) the optimization problem has a bounded continuous solution for K given by the optimal decision rules. Contrary to static models, condition (B.v) requires third order curvature conditions for guaranteeing that the first order conditions result in a global minimum in (4.2). Under static price expectations, these third order conditions are satisfied if the shadow prices for installed capital are linear in prices (Lemma 1 in Epstein 1981). We will return to a discussion of conditions (B.v) in the context of our model in more detail below. With an instantaneous cost function that is positively linearly homogenous in prices (W,Q) condition (B.vi) follows from the result of Abel and Eberly (1994)[7].

The condition $(\nabla_K J)' < 0$, for all $I > 0$ in (B.ii) can be generalized. First differentiate (4.6) with respect to I and then add the complementary slackness condition to get

$$I\left[\nabla_I C' + \nabla_K J'\right] = 0, \; for \; all \; I$$

which, within the partition of I, gives the following links between the regularity conditions of C and J

$$\nabla_K J' < 0, \; for \; all \; I > 0, \; if \; \nabla_I C' > 0$$

$$\nabla_K J' > 0, \; for \; all \; I < 0, \; if \; \nabla_I C' < 0$$

$$(\nabla_I C(I{=}0)^-)' \leq -\nabla_K J' \leq (\nabla_I C(I{=}0)^+)', \; for \; all \; I = 0$$

where $^-$ and $^+$ superscripts refer to left- and right-hand side gradients. In other words, if the optimal investment is positive, the discounted present value of the cost stream (the optimal value function) is decreasing with the capital stock, and vice versa. Zero gross investment

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7 The rental price vector (Q) is related to the purchasing price vector (P) through the equation: $Q=(r+\delta)P$. When Q is varied in the spirit of (B.vi) the discount rate r is held fixed, and the variation is driven up by variation in P.

is chosen if the (negative of the) shadow price of capital is between the marginal cost of disinvesting and investing. Therefore, if we observe $(\nabla_K J)' < 0$ at $I=0$, then $(\nabla_I C(I=0)^{+})' > 0$ must hold. The value function is decreasing with the capital stock, but the frictions make zero investment optimal. Similarly, if $(\nabla_K J)' > 0$ at $I=0$ then $(\nabla_I C(I=0)^{-})' < 0$ holds. The value function increases with the capital stock but frictions prevent disinvestment.

Following Epstein (1981) and Epstein and Denny (1983), an inverse problem to (4.6) is:

$$C = \max_Q \left\{ rJ - \nabla_Z J \mu(Z) - \nabla_K J(I - \delta K) - \frac{1}{2}[Vec(\nabla_Z^2 J)]'[Vec(\Sigma)] \right\}$$

There are two differentiability conditions that needs to be clarified for obtaining a unique solution to this maximization problem. First, if C is convex (concave) in I, then $\nabla_K J$ must be concave (convex) in Q. This condition is, nevertheless, always met if $\nabla_K J$ is linear in Q.

Second, because C is concave in prices (Q) the right hand side term

$$rJ - \nabla_Z J \mu(Z) - \nabla_K J(I - \delta K) - \frac{1}{2}[Vec(\nabla_Z^2 J)]'[Vec(\Sigma)]$$

has to be concave in prices, too. This curvature condition is met, for example, if

(D.i) J is concave in prices (=B.iii),

(D.ii) $\nabla_Z J \mu(Z)$ is convex in prices,

(D.iii) $\nabla_K J$ is linear in prices, as above, and

(D.iv) $\nabla_Z^2 J$ is linear in prices.

Condition (D.i) was already set in (B.iii) and condition (D.iii) was set above, therefore, neither of them adds more restrictions in the model. Condition (D.ii) is always met if μ(Z)=0, i.e. expectations are static. But in the case with nonzero μ(Z), (D.ii) is certainly met if both $\nabla_Z J$ and μ(Z) are convex in Q. For example, if $\nabla_Z^2 J$ is linearly nondecreasing in prices and μ(Z) is convex in prices then (D.ii) is satisfied. To see this, suppose we impose $\nabla_Z^2 J$ to be linearly nondecreasing in prices, so that $\frac{\partial^2 J}{\partial z_i^2} = \varphi_i q_i \geq 0$, where φ_i is a nonnegative parameter and i refers to the elements of Z corresponding to input prices. Because they are the logarithms of input prices that appear in Z we can write the convexity condition as (in scalar notation)

$$\frac{\partial^2(\partial J/\partial z_i)}{\partial q_i^2} = \frac{\partial[(\partial^2 J/\partial z_i^2)(\partial \ln q_i/\partial q_i)]}{\partial q_i} = \frac{\partial[(\varphi_i q_i)(q_i)]}{\partial q_i} = 2\varphi_i q_i \geq 0$$

which says that the convexity requirement is met for all φ_i ≥0.

Concerning the requirements for μ, on the other hand, the convexity condition can be made in practice without much loss of generality. For example, a stationary VAR(1) process or a nonstationary VAR(1) process with unit roots estimated on logarithms of prices will result in convex μ[8]. And, as mentioned above, unit roots in the univariate series for prices will result in a trivial case of $\nabla_Z J \mu(Z) = 0$ no matter what the properties of $\nabla_Z J$ are.

Thus, the regularity conditions (D) required for a stochastic dual model with rational expectations do not further restrict the regularity conditions of J compared to its deterministic and/or static expectations counterparts. Strong restrictions do not need to be imposed on the empirical specification of expectations either, as long as they follow a VAR(1) process. A consistent model can be estimated for example with the following properties (D')[9]:

(D'.i) J is concave in prices,

(D'.ii) μ(Z) is convex in prices, i.e. Z in (4.1) follows either a stationary VAR(1) or nonstationary VAR(1) with unit roots.

(D'.iii) $\nabla_K J$ is linear in prices, and

(D'.iv) $\nabla_Z^2 J$ is linearly nondecreasing in prices.

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[8] We use the approximation $\dot{Z} \approx Z_{t+1} - Z_t$. Note that estimating the VAR(1) on levels of prices results in linear μ and, the convexity condition is met in this case for all stationary and nonstationary series.

[9] The regularity conditions discussed in Luh and Stefanou (1996) relate to a profit maximization model in which the evolution of future prices is nonstatic but known with certainty, i.e. their model is deterministic. It is straightforward to generalize the regularity conditions presented here to a stochastic profit maximization problem.

It will be shown below that our model meets the regularity conditions (D').

Now the optimization problem and the resulting regularity conditions are set. The observed optimal decision rules (the investment schedules and the demand for variable inputs) are derived from (4.6) by differentiating and using the envelope theorem, but first a functional form must be specified for the optimal value function J.

4.7 Specification for the Optimal Value Function

The optimal value function is a function of the capital stock, output, and prices. We specify the quantity index of capital stock K or, more specifically, the stock of quasi fixed inputs as having three elements: real estate, machinery, and labor. Output, Y, is aggregated into two indices: livestock and crop output indices. The logarithms of these output indices are stacked into a vector lnY. An aggregate variable input is denoted by x, and includes fertilizers, feed, chemicals, and energy. The price index of the variable input is used as a numéraire, and the logarithms of the normalized rental prices of the quasi-fixed inputs are stacked into a vector lnQ. Therefore, the optimal value function depends on the following vectors:

$K = [k_1, k_2, k_3]'$

$Y = [y_1, y_2]'$ $\qquad lnY = [lny_1, lny_2]'$

$\dot{Q} = [q_1, q_2, q_3]'$ $\qquad lnQ = [lnq_1, lnq_2, lnq_3]'$

Further, the exogenous output level and input prices are stacked into vector $Z = [lnY, lnQ]'$. The optimal value function is assumed to be additively separable from prices and inputs of other goods.

A quadratic second order approximation with respect to the capital stock (K) and the logarithm of output and prices (Z) is used as a functional form for the optimal value function. The necessary third order curvature conditions in (D'.iii) are imposed on the model by assuming that the shadow price of installed capital is linear in prices. With these restrictions, the optimal value function (J) has the following form

$$J(K,Y,Q) = a_0 + a'\begin{bmatrix} K \\ lnY \\ lnQ \end{bmatrix} + \frac{1}{2}\begin{bmatrix} K' & lnY' & lnQ' \end{bmatrix}\begin{bmatrix} A & E & 0 \\ E' & B & H \\ 0 & H' & D \end{bmatrix}\begin{bmatrix} K \\ lnY \\ lnQ \end{bmatrix} + Q'M^{-1}K \qquad \textbf{(4.7)}$$

We have specified J with an inverted parameter matrix M^{-1}, because then the matrix M appears in the optimal decision rules.

To obtain the terms in the necessary condition (4.6), first differentiate the value function to obtain the (transposed) gradient vectors:

$$\nabla_{K}J' = a_1 + AK + ElnY + M^{-1}Q$$

$$\nabla_{Z}J' = \begin{bmatrix} a_2 + E'K + BlnY + HlnQ \\ a_3 + H'lnY + DlnQ + M^{-1}K \odot Q \end{bmatrix} \qquad \textbf{(4.8)}$$

where $\odot$ = *element by element multiplication*
(*the Hadamard product*)

Then, differentiate the transposed gradient $\nabla_Z J'$ to obtain the Hessian of J as

$$\nabla_{Z}^{2}J = \begin{bmatrix} B & H \\ H' & D + M^{-1}K\frac{\partial^2 Q}{\partial lnQ^2} \end{bmatrix},$$

$$\textbf{(4.9)}$$

$$where\ M^{-1}K\frac{\partial^2 Q}{\partial lnQ^2} = \frac{\partial(M^{-1}K \odot Q)}{\partial lnQ} = Diag\{(M^{-1}K \odot Q)_j\}$$

j refers to the j^{th} *element in the vector* $M^{-1}K \odot Q$

Performing differentiation we then get

$$\nabla_Z^2 J = \begin{bmatrix} B & H \\ H' & D + \begin{bmatrix} q_1 \sum_{j=1}^{3} m_{1j}^{-1} k_j & 0 & 0 \\ 0 & q_2 \sum_{j=1}^{3} m_{2j}^{-1} k_j & 0 \\ 0 & 0 & q_3 \sum_{j=1}^{3} m_{3j}^{-1} k_j \end{bmatrix} \end{bmatrix}$$

$$where\ m_{sj}^{-1} = (s,j)^{th}\ element\ in\ M^{-1}$$

Note that $\nabla_Z^2 J$ is linearly nondecreasing in prices (Q), provided M is positive definite. Thus, the model meets the regularity condition in (D'iv).

4.8 Optimal Decision Rules

The observed optimal decision rules are derived from (4.6) by differentiating and using the envelope theorem. Substituting (4.1) and (4.7)-(4.9) into (4.6), differentiating (4.6) with respect to *lnQ*, and taking expectations results in,

$$r(\nabla_{lnQ}J)' = (\nabla_{lnQ}C)' + (\nabla_{ZlnQ}J)\mu(Z) + \left(\nabla_{lnQ}\mu(Z)\right)'(\nabla_Z J)'$$
$$+ (\nabla_{KlnQ}J)\dot{K} + \frac{1}{2}\partial Vec(\nabla_Z^2 J)' Vec(\Sigma)/\partial lnQ$$

$$\textit{where} \quad (\nabla_{lnQ}C)' = (U+\gamma)K \odot Q$$

$$\nabla_{ZlnQ}J' = \left[H' \;\; D + Diag(M^{-1}K \odot Q)_j\right]$$

$$\nabla_{lnQ}\mu(Z) = \textit{Jacobian of } \mu(Z) \textit{ with respect to } lnQ \qquad \textbf{(4.10)}$$

$$\nabla_Z J \textit{ is given in } (4.8)$$

$$(\nabla_{KlnQ}J)\dot{K} = M^{-1}\dot{K} \odot Q \quad \textit{and}$$

$$\partial Vec(\nabla_Z^2 J)' Vec(\Sigma)/\partial lnQ = M^{-1}K \odot Q \odot [\sigma_{q1}^2 \;\; \sigma_{q2}^2 \;\; \sigma_{q3}^2]'$$

$$\sigma_{qj}^2 = \textit{variance of the } j^{th} \textit{ input price, } q_j$$

Solving for $\dot{K}$ we get

$$\dot{K} = Diag\{q_j^{-1}\} M\left[r(\nabla_{lnQ}J)' - (\nabla_{ZlnQ}J)\mu(Z) - (\nabla_{lnQ}\mu(Z))'\nabla_Z J'\right]$$
$$- (U+\gamma)MK - \frac{1}{2}K \odot \left[\sigma_{q1}^2 \;\; \sigma_{q2}^2 \;\; \sigma_{q3}^2\right]'$$

Where $Diag\{q_j^{-1}\}$ *is a diagonal matrix with* q_j *as* j^{th} *diagonal element*

Then, we pin down the structural parameters in J by assuming static price and output expectations such that Z follows a simple Brownian motion without drift. In other words, we set $\mu(Z) = \nabla_{lnQ}\mu(Z) = 0$. Although, the parameters in $\mu(Z)$ could be identified in the price and output equations (4.1), the decision rules (equations for $\dot{K}$) do not provide any overidentification restrictions for testing whether the expectations follow (4.1) or not. The reason is that the three terms $r(\nabla_{lnQ}J)$, $(\nabla_{ZlnQ}J)\mu(Z)$, *and* $(\nabla_{lnQ}\mu(Z))'\nabla_Z J$ are all functions of *Y, Q,* and *K*. Technically, we could obtain over identification restrictions, for example, through imposing a specific functional form for $\mu(Z)$, but it would not be good econometric practice, and it is not exploited here, because we could not distinguish between misspecified expectations and misspecified functional form.

Now, it is easy to see that by allowing for $\mu(Z) \neq 0$ we would only split the parameters which multiply *Z* in the decision rules into two fractions. The sum of these two fractions, however, would remain unchanged no matter how we split the parameters into these two fractions. Furthermore, partial derivatives and elasticities of the decision rules with respect to *Z* would remain unaltered by the specification of $\mu(Z)$.

There are no overidentification restrictions for testing the parameters σ^2_{q1}, σ^2_{q2}, *and* σ^2_{q3} in the term $-\frac{1}{2}K \odot \begin{bmatrix}\sigma^2_{q1} & \sigma^2_{q2} & \sigma^2_{q3}\end{bmatrix}'$ either. Nevertheless, this term can be used for modeling an identified regime shift in which we observe a persistent shift in uncertainty. In other words, by using properly defined dummy variables we can model how the conjectured increase in uncertainty at the beginning of 1991 has affected farmers' investment behavior.

By making substitutions for $\nabla_{lnQ}J$, $\nabla_{ZlnQ}J$, $\nabla_Z J$, Z, *and* $\mu(Z)$, and by collecting terms, we obtain

$$\begin{aligned}\dot{K} &= Diag\{q_j^{-1}\} M\left(ra_3 + rH'lnY + rDlnQ\right) \\ &+ \left(rU - (U + \gamma)M\right)K \\ &- \frac{1}{2}\left[\sigma_{q1}^2 \;\; \sigma_{q2}^2 \;\; \sigma_{q3}^2\right]' \odot K\end{aligned} \qquad \textbf{(4.11a)}$$

Note that $\partial\dot{k}_j/\partial\sigma_{qj}^2 = -\frac{1}{2}k_j < 0$ for all j=1,2,3 in (4.11a), and optimal investment decreases with the volatility of own price. In other words, volatile capital prices slow down capital expansion. Also note that the matrix M multiplies the price effects. Therefore, if the elements of M are small but they exceed r, the capital stock will adjust slowly towards its steady state level and demand is inelastic in the short run with respect to changes in prices and output.

In the deterministic case with static expectations, such that $\mu_j = 0$ for all j and with the assumption of $\gamma=0$, the optimal investment schedules coincide with the widely used constant coefficient multi-variate flexible accelerator of the form $\dot{K} = (rU - M)(K - \bar{K})$, where $(rU - M)$ and $\bar{K}$ stand for a matrix of adjustment rates and a steady state capital stock.

The demand for the numéraire input x is solved from the HJB-equation. Recall that with only one variable input, x, which is used as a numéraire, the instantaneous cost function C^{η} equals x. Then, the HJB becomes[10]:

$$rJ = x + (U+\gamma)Q'K + \nabla_Z J\mu(Z) + \nabla_K J\dot{K}^* + \frac{1}{2}[Vec(\nabla_Z^2 J)]'[Vec(\Sigma)],$$

where $\dot{K}^*$ refers to its optimal value. By solving the HJB for x we get:

$$x = rJ - (U+\gamma)Q'K - \nabla_Z J\mu(Z) - \nabla_K J\dot{K}^* - \frac{1}{2}[Vec(\nabla_Z^2 J)]'[Vec(\Sigma)],$$

which is rearranged further by making the familiar substitutions for $\nabla_{lnQ}J$, $\nabla_{ZlnQ}J$, $\nabla_Z J$, Z, and $\mu(Z)$ as in (4.11a)[11]:

$$\begin{aligned} x = {} & a_{x0} + a_1'(rK - \dot{K}^*) + a_2' lnY + a_3' lnQ \\ & + K'A(\frac{r}{2}K - \dot{K}^*) + lnY'E'(rK - \dot{K}^*) \\ & + \frac{1}{2}lnY'BlnY + lnY'H(lnQ - 1) + \frac{1}{2}lnQ'D(lnQ - 2), \end{aligned} \quad \textbf{(4.11b)}$$

$$where\ a_{x0} = an\ intercept$$

[10] The equation is subject to the same constraints as (4.6).

[11] Constant terms are included in the intercept and, therefore, a_{x0} is not the same as a_0 in J.

The economic model consists of four decision rules (4.11): net investment on real estate, $\dot{k}_1$; net investment on machinery, $\dot{k}_2$; the change in the labor input, $\dot{L}$; and the demand for the numéraire input, x. For fitting the model to data, the discrete approximation $\dot{K}_t \approx K_{t+1} - K_t$ is used. The net investments, $\dot{K}$, are solved further for gross investments, I, by using the equality $i_j = \dot{k}_j + \delta_j k_j$, for j=1,2. The term δ refers to the geometric depreciation rate as above.

The decision rules are given in terms of the structural form parameters that appear in the optimal value function, J. Thus, the parameter estimates can be used for testing hypotheses that are linked to the characteristics of the instantaneous cost function through the conditions given above. The decision rules also give a direct way to make inferences about the short-term investment responses and long-term responses of the capital stock. We can also compare the observed and steady state capital stocks and, assuming the increased policy risks are realized through increased volatility of prices, the response of the investments on the conjectured increase in policy risk can be tested through the parameters of price variances in (4.11a). We now move on to the technique for estimating the optimal decision rules, which is presented in the next chapter.

Chapter 5

ESTIMATING THE MODEL

This chapter describes econometric estimation of the decision rules given in the preceding chapter. We first characterize the assumptions underlying the model, and then move on to the statistical specification of the decision rules. The last section gives a detailed description of the estimators, concluding with the likelihood function used for estimating the decision rules.

5.1 Assumptions Underlying the Model

The statistical model is constructed under three specific assumptions which allow the decision rules to be estimated separately from the output and price equations. This reduces considerably the computational complexity of the estimation procedure. The assumptions are justified by obtaining a feasible estimation procedure and, in particular, a statistical model that was found to converge.

First, we assume that the output and price series follow a nonstationary geometric Brownian motion without drift, i.e. we set $\mu(Z)=0$ in (4.1). An autoregressive model and the ordinary least squares technique (OLS) will be used for testing whether the observed output and price series show strong evidence against the null hypothesis of zero drift. The testing procedure is discussed in Chapter 7 together with a report of the results.

Second, we assume that the error terms in the decision rules are independent of the error terms in the transition equations. These covariance restrictions are maintained without testing, because it was not possible to estimate the transition equations jointly with the decision rules. This may reduce the efficiency of the estimates but they remain consistent.

Third, with regard to the parameters measuring volatility of the input prices, we model only a regime shift, i.e. a single persistent shift in uncertainty, which occurred at the beginning of 1991. As explained in the preceding chapters, it seems likely that price uncertainty increased at the beginning of 1991 when the debate on Finland's possible entry to the European Union started. The effects of this increased uncertainty on farmers' investment behavior are modeled and tested through dummy variables over the period 1991-93.

5.2 Specification of the Decision Rules

The equations for the net investments $\dot{k}_1$ *and* $\dot{k}_2$ are solved for the gross investments i_1 *and* i_2 using the equalities $i_j = \dot{k}_j + \delta_j$, *for* $j = 1,2$, where δ is the geometric depreciation rate. There are four decision rules corresponding to the choice of real estate investment, i_l;

machinery investment, i_2; change in the labor input, $\dot{L}$; and demand for the other inputs (the numéraire), x. As explained in the chapters above, the optimal decision rules have both discrete and continuous characteristics. We observe positive values and zeros for gross investments in real estate and machinery. Strictly speaking, the zero investments do not result from data truncation or censoring, but from the frictions that make them optimal choices. Nonetheless, our statistical model coincides with a model for censored data and has the same structure as a simultaneous Tobit model with two censored variables, i_1 *and* i_2. The change in the labor input, on the other hand, has both negative and positive observations but no zeros. We model the labor changes and the demand for the numéraire input assuming they are continuous in the state space, and observed without limits. Therefore, the estimating equations are

$$
\begin{aligned}
i_1^* &= \bar{Z}\theta_{i1} + \varepsilon_1 \\
&\qquad i_1 = i_1^* \ \textit{if} \ i_1^* > 0 \\
&\qquad = 0 \ \textit{if} \ i_1^* \leq 0 \\
i_2^* &= \bar{Z}\theta_{i2} + \varepsilon_2 \\
&\qquad i_2 = i_2^* \ \textit{if} \ i_2^* > 0 \\
&\qquad = 0 \ \textit{if} \ i_2^* \leq 0 \\
\dot{L} &= \bar{Z}\theta_l + \varepsilon_3 \\
x &= (\bar{Z}, i_1, i_2, \dot{L})\theta_x + \varepsilon_4
\end{aligned}
\tag{5.1}
$$

where $\bar{Z} = g(Z, k_1, k_2, L)$

g is a function

θ_{i1}, θ_{i2}, θ_l, *and* θ_x *are subsets of the parameters in the optimal value function J* and where the terms i_1^* *and* i_2^* refer to the latent form investments, which are uncensored but not observed. The uncensored latent form investments have an interpretation as desired investments. That is, the latent forms refer to the optimal investments under a hypothetical condition in which the frictions, driven by uncertainty and fixed adjustment costs, were not apparent[1].

For later purposes we simplify the notation by partitioning the decision rules into two sets: $I = (i_1, i_2)$, $(or\ I^* = (i_1^*, i_2^*))$, $and\ X = (\dot{L}, x)$. The partition *I* has the variables that are bounded to be nonnegative. The partition *X*, on the other hand, has only continuous variables that are unlimited in their range.

In our notation, the same set of exogenous variables appears on the right-hand side of each Equation (5.1). Exclusion restrictions, implied by the economic model, are imposed by setting the appropriate parameters to zero. Equations for the censored investment demands have neither censored variables nor any other endogenous right-hand side variables. These exclusion restrictions guarantee that the model is internally consistent and a unique solution is identified for both investment demands. [2]

---

[1] The standard adjustment costs that are convex in investment result in investment smoothing but do not result in zero investments.

[2] If the censored investments appeared in the right-hand sides of the investment demands, we could get two reduced form solutions for i_1 and none for i_2, or vice versa, unless certain inequality restrictions were imposed on the parameters For more details, see Schmidt (1981).

The equation for x has three endogenous right-hand side variables, i_1, i_2, and $\dot{L}$. But all of the elements in θ_x are identified by the parameter restrictions between and within the equations that are, again, implied by the economic model. Note that it is the observed investments, not the unobserved latent form investments, which determine the endogenous treatment effect in the demand for x. The treatment effect is linear in i_1, i_2 or $\dot{L}$, but it is not constant. It interacts with the firm's current output and capital stock, including labor (see Equation 4.11b).

5.3 Estimators

The model can be estimated consistently by two different classes of methods: (1) by the two-stage method; or (2) by full information maximum likelihood methods (FIML). The two-stage method, originally suggested by Heckman (1976), can be applied to a wide class of models using standard estimation techniques. It can provide consistent estimates for complex problems even under certain nonstandard assumptions. [3]

Heckman's method could be used to estimate the investment decisions if they are conceived as a two stage decision. The endogenous choice of regime, i.e. whether to invest or postpone investment, could be modeled first as a binary choice and estimated by the

---

[3] For example, a serially correlated, heteroscedastic, or nonnormally distributed error term. The Tobit MLE is inconsistent under heteroscedasticity or nonnormality (Amemiya 1985).

maximum likelihood technique. Then, at the second stage, the decision "how much to invest if you decided to invest in the first stage" could be estimated by a least squares method, with correction for the bias caused by the endogenous regime selection. The nonstandard assumptions mentioned above apply to the second stage estimation only. Obtaining consistent parameter estimates by the two-stage method is relatively straightforward and can be done by most econometric software. Nevertheless, obtaining the correct standard errors for the parameter estimates requires complex computations which are not usually given in standard software output. The reason for this is that the inverses of the Mills ratios, which are added as regressors in the second stage estimation for correcting the selectivity bias, are not observed in the data. They are estimated, which should be accounted for when computing the standard errors in the second stage.

If the FIML method is used, the investment decision can be modeled as a simultaneous decision such that the decisions "invest or not" and "how much to invest" are made simultaneously. Under the assumption of a normally, identically, and independently distributed error term (Normal i.i.d.), the FIML provides estimators that are efficient among all estimators (Amemiya 1985). The FIML method will be used in the study.

We assume the errors $\{\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4\}$ are i.i.d. drawings from a multi-variate Normal distribution with zero mean and a symmetric (4x4) covariance matrix Σ whose lower triangle is given by[4]

[4] The normality assumption will be tested below by a general test for misspecification.

$$\Sigma = \begin{bmatrix} \Sigma_1 & \\ \Sigma_{21} & \Sigma_2 \end{bmatrix} = \begin{bmatrix} \sigma_1^2 & & & \\ \sigma_{21} & \sigma_2^2 & & \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 & \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_4^2 \end{bmatrix} \tag{5.2}$$

where the matrices Σ_1 (2x2) and Σ_2 (2x2) correspond to the partitions I and X

In other words, we assume the demands for i_1, i_2, $\dot{L}$, *and* x are i.i.d. drawings from a multivariate normal distribution with means $\bar{Z}\theta_{i1}$, $\bar{Z}\theta_{i2}$, $\bar{Z}\theta_{il}$, *and* $(\bar{Z},i_1,i_2,\dot{L})\theta_x$, and with a covariance matrix Σ.

Denote a density function by $f^d(.)$ and the corresponding cumulative density function by $F^d(.)$. Then the joint densities for the partitions $I^* = (i_1^*, i_2^*)$ and X can be decomposed into three equivalent products of conditional and marginal densities [5]:

[5] Rigorously, all densities are conditioned on a set of variables, but the terms marginal or conditional density are used if the conditioned set excludes or includes endogenous variables.

$$
\begin{aligned}
f^d(X,I^*|\bar{Z},\theta) &= f^d(X|\bar{Z},\theta)\, f^d(I^*|X,\bar{Z},\theta) \\
&= f^d(X|\bar{Z},\theta)\, f^d(i_2^*|X,\bar{Z},\theta)\, f^d(i_1^*|i_2^*,X,\bar{Z},\theta) \\
&= f^d(X|\bar{Z},\theta)\, f^d(i_1^*|X,\bar{Z},\theta)\, f^d(i_2^*|i_1^*,X,\bar{Z},\theta)
\end{aligned}
\qquad \textbf{(5.3)}
$$

$$\textit{where } \theta = \textit{a set of parameters}$$

The vectors Z and X are observed for every observation in the sample, but i_1^* *and* i_2^* are observed only when they are greater than zero. When constructing the likelihood function, the unobserved latent form variables, i_1^* *and* i_2^*, are replaced by their observed counterparts i_1 *for all* $i_1^* > 0$ *and* i_2 *for all* $i_2^* > 0$.

As explained in the preceding chapters, the data are endogenously partitioned into four investment regimes, which are:

(1) $i_1>0$ *and* $i_2>0$
(2) $i_1=0$ *and* $i_2>0$
(3) $i_1>0$ *and* $i_2=0$
(4) $i_1=0$ *and* $i_2=0$

Then, incorporate the investment regimes and the cumulative distributions which measure the probabilities for negative latent form investments, i.e. for observed zero investments, into (5.3) and get the density [6]:

---

[6] This is a special case of the models in Maddala (1983).

$$
\begin{aligned}
f^d(X,I|\bar{Z},\theta) = {} & f^d(X|\bar{Z},\theta) \\
& f^d(I|X,\bar{Z},\theta)^{[i_1>0][i_2>0]} \\
& \left\{f^d(i_2|X,\bar{Z},\theta)\ F^d(i_1^*<0|i_2,X,\bar{Z},\theta)\right\}^{[i_1=0][i_2>0]} \\
& \left\{f^d(i_1|X,\bar{Z},\theta)\ F^d(i_2^*<0|i_1,X,\bar{Z},\theta)\right\}^{[i_1>0][i_2=0]} \qquad \textbf{(5.4)} \\
& F^d(i_1^*<0,i_2^*<0|X,\bar{Z},\theta)^{[i_1=0][i_2=0]}
\end{aligned}
$$

$$
where\ [.] = \begin{cases} 1 & if\ the\ statement\ is\ true \\ 0 & otherwise \end{cases}
$$

Then, substituting the normal density and cumulative density functions into (5.4) and taking logarithms result in the loglikelihood function for an individual observation. The function is:

$$
\ell = \ell_1 + [i_1>0][i_2>0]\,\ell_2 + [i_1=0][i_2>0]\,\ell_3 + [i_1>0][i_2=0]\,\ell_4 + [i_1=0][i_2=0]\,\ell_5 \qquad \textbf{(5.5)}
$$

where ℓ_1 is the logarithm of the normal joint density of X conditional on Z[7]:

$$\ell_1 = -\frac{1}{2}\ln|\Sigma_2| - \frac{1}{2}\left(X - E(X|\bar{Z})\right)' \Sigma_2^{-1}\left(X - E(X|\bar{Z})\right)$$

$$\textit{where } E(X|\bar{Z}) = \begin{bmatrix} E(\dot{L}|\bar{Z}) \\ E(x|\bar{Z}) \end{bmatrix} = \begin{bmatrix} \bar{Z}\theta_l \\ \left(\bar{Z}, E(i_1|\bar{Z}), E(i_2|\bar{Z}), E(\dot{L}|\bar{Z})\right)\theta_x \end{bmatrix}$$

$$E(i_j|\bar{Z}) = \Phi(\bar{Z}\theta_{ij}/\sigma_j)\bar{Z}\theta_{ij} + \sigma_j\phi(\bar{Z}\theta_{ij}/\sigma_j) \quad \textit{for } j = 1,2$$

$$\Phi(.) = \textit{standard normal cumulative density function (cdf)}$$

$$\phi(.) = \textit{standard normal density function}$$

And ℓ_2 denotes the logarithm of the normal joint density of I conditional on X *and* Z:

$$\ell_2 = -\frac{1}{2}\ln|\Sigma_1 - \Sigma_{12}'\Sigma_2^{-1}\Sigma_{12}|$$

$$-\frac{1}{2}(I - m_I)'\left[\Sigma_1 - \Sigma_{12}'\Sigma_2^{-1}\Sigma_{12}\right]^{-1}(I - m_I)$$

$$\textit{where } m_I = \left[\bar{Z}\theta_{i1} \quad \bar{Z}\theta_{i2}\right]' + \Sigma_{12}'\Sigma_2^{-1}\left(X - E(X|\bar{Z})\right)$$

[7] Conditional densities have been computed following Maddala (1983), Amemiya (1985), and Hamilton (1994). The constants not affecting the maximization have been dropped.

The term ℓ_3 is the logarithm of the normal density of i_2 conditional on X *and* Z plus the logarithm of the normal cumulative density function of i_1 conditional on i_2, X *and* Z evaluated at $i_1=0$ *and* $i_2>0$:

$$\begin{aligned}
\ell_3 = & -\frac{1}{2}\ln\left(\sigma_2^2 - [\sigma_{23}\,\sigma_{24}]\Sigma_2^{-1}[\sigma_{23}\,\sigma_{24}]'\right) \\
& -\frac{1}{2}(i_2 - m_{21})^2\left(\sigma_2^2 - [\sigma_{23}\,\sigma_{24}]\Sigma_2^{-1}[\sigma_{23}\,\sigma_{24}]'\right)^{-1} \\
& + \ln\Phi\left(-m_{12}\sigma_{m12}^{-1}\right)
\end{aligned}$$

$$\begin{aligned}
\textit{where } m_{21} &= \bar{Z}\theta_{i2} + [\sigma_{23}\,\sigma_{24}]\Sigma_2^{-1}\left(X - E(X|\bar{Z})\right) \\
m_{12} &= \bar{Z}\theta_{i1} + [\sigma_{12}\,\sigma_{13}\,\sigma_{14}](\Sigma_{-1})^{-1}\begin{bmatrix} i_2 - \bar{Z}\theta_{i2} \\ X - E(X|\bar{Z}) \end{bmatrix} \\
\sigma_{m12}^2 &= \sigma_1^2 - [\sigma_{12}\,\sigma_{13}\,\sigma_{14}](\Sigma_{-1})^{-1}\begin{bmatrix} \sigma_{12} \\ \sigma_{13} \\ \sigma_{14} \end{bmatrix} \\
\Sigma_{-1} &= \begin{bmatrix} \sigma_2^2 & \sigma_{23} & \sigma_{24} \\ \sigma_{32} & \sigma_3^2 & \sigma_{34} \\ \sigma_{42} & \sigma_{43} & \sigma_4^2 \end{bmatrix}
\end{aligned}$$

The term ℓ_4 is similar to ℓ_3, but variables and parameters are switched. Thus, ℓ_4 refers to the normal density of i_1 conditional on i_2 *and* Z plus the normal cumulative density function of i_2 conditional on Z evaluated at the regime, in which $i_1>0$ *and* $i_2=0$:

$$\begin{aligned}
\ell_4 = & -\frac{1}{2}\ln\left(\sigma_1^2 - [\sigma_{13}\,\sigma_{14}]\Sigma_2^{-1}[\sigma_{13}\,\sigma_{14}]'\right) \\
& -\frac{1}{2}(i_1 - m_{11})^2\left(\sigma_1^2 - [\sigma_{13}\,\sigma_{14}]\Sigma_2^{-1}[\sigma_{13}\,\sigma_{14}]'\right)^{-1} \\
& + \ln\Phi\left(-m_{22}\sigma_{m22}^{-1}\right)
\end{aligned}$$

$$\textit{where}\ m_{11} = \bar{Z}\theta_{i1} + [\sigma_{13}\,\sigma_{14}]\Sigma_2^{-1}(X - E(X|\bar{Z}))$$

$$m_{22} = \bar{Z}\theta_{i2} + [\sigma_{21}\,\sigma_{23}\,\sigma_{24}](\Sigma_{-2})^{-1}\begin{bmatrix} i_1 - \bar{Z}\theta_{i1} \\ X - E(X|\bar{Z}) \end{bmatrix}$$

$$\sigma_{m22}^2 = \sigma_2^2 - [\sigma_{21}\,\sigma_{23}\,\sigma_{24}](\Sigma_{-2})^{-1}\begin{bmatrix} \sigma_{21} \\ \sigma_{23} \\ \sigma_{24} \end{bmatrix}$$

$$\Sigma_{-2} = \begin{bmatrix} \sigma_1^2 & \sigma_{13} & \sigma_{14} \\ \sigma_{31} & \sigma_3^2 & \sigma_{34} \\ \sigma_{41} & \sigma_{43} & \sigma_4^2 \end{bmatrix}$$

The term ℓ_5 refers to a bivariate cumulative normal density for i_1 *and* i_2 conditional on X *and* Z evaluated at $i_1 = 0$ *and* $i_2 = 0$:

$$\ell_5 = \Phi^B\left(-m_{11}\sigma_{m11}^{-1}, -m_{12}\sigma_{m12}^{-1}\right)$$

$$\text{where } \Phi^B = \text{standard bivariate normal cdf}$$

$$\sigma_{m11}^2 = \sigma_1^2 - \left[\sigma_{13}\,\sigma_{14}\right]\Sigma_2^{-1}\left[\sigma_{13}\,\sigma_{14}\right]'$$

$$\sigma_{m21}^2 = \sigma_2^2 - \left[\sigma_{23}\,\sigma_{24}\right]\Sigma_2^{-1}\left[\sigma_{23}\,\sigma_{24}\right]'$$

For obtaining the sample loglikelihood function, Equation (5.5) is summed over the observations. The loglikelihood function is maximized using GAUSS software with the Constrained Maximum Likelihood (CML) routine. Now, the statistical model is set, and the next chapter explains the data used for estimating the model.

Chapter 6

DATA

This chapter discusses data sources and provides graphs and summary statistics for the data. The optimal decision rules were defined in Chapter 4 as functions of input prices, output level, and the capital stock, including labor. All price indices except land are obtained from the index series of the Agricultural Economics Research Institute (AERI) at Helsinki, or from the index series of the Statistical Office of Finland. Each series has one observation a year and they are chain-linked Laspeyres indices, so current prices are used as a base in estimating the rate of growth to the following year.

The farm level data on investments, capital accumulation, output levels, and variable input use are from Finnish bookkeeping hog farms over the period 1976-1993. The bookkeeping program is managed by AERI and surveyed by the county extension offices. The data are summarized by annual income accounts and by balance sheets at the beginning and at the end of each year.

The panel data span 18 years, but the panel is not balanced. The duration of each farm's participation in the program over the study period varies as shown in Figure 6.1. The total number of farms in the data is 316, but only 23 farms participated in the program over the entire study period. The 41 farms that participated only one year were dropped from the

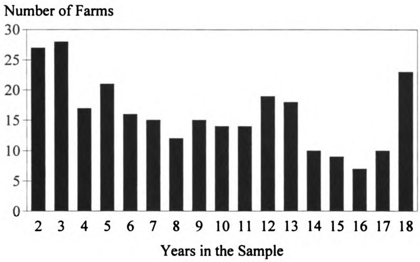

Figure 6.1. Frequency of the Farms' Duration in the Sample[1].

sample, because we could not construct lagged variables for those observations. Hence, we were left with 275 farms. The average number of observations per year is 137, varying between 83 (in 1976) and 169 (in 1988). The total number of observations is 2,470, but 1,928 observations are used in estimating the decision rules.[2]

Not all the quantity and price indices needed for estimating the economic model are observed directly. But the unobserved indices are computed and aggregated from more

---

[1] The duration of one Year has been eliminated and the duration is censored from the right by the number of sampling years.

[2] Some observations were dropped from the sample. For example, we could not compute lagged values for all of the observations in the original data set, because the panel data were not balanced.

micro observed quantities, expenditures, revenues, and price indices. The data and the computation of the variables in the economic model are described in detail below.

6.1 Price Indices

6.1.1 Real Estate

Real estate is aggregated from three component goods: land, buildings, and drainage. Because there are no data on quantities of the component goods, except for land, a Divisia price index for real estate was computed using the expenditure shares and prices of the component goods. In addition, the price for land is not observed and must also be estimated.

Price of Land

Average annual rental prices and discount rates are used to value land, because land trading transactions data are insufficient to determine reliable purchase prices of land. The data have 1,326 land leasing cases, varying from 42 to 93 per year, but there are only 135 land purchasing cases. In every leasing case the sample farm was a tenant, not a lessor. The average leased area per tenant was 12.0 hectares. Across all the sample farms, the average leased area was 6.42 hectares and 19.2 % of the arable land area.

No information about the characteristics of leasing contracts is observed, but most leasing cases are expected to be cash leases with predetermined lease payments. In 1991, for example, only five percent of land leased in Finland were share leases or leases in which payments were made in kind (Ylätalo and Pyykkönen 1992).

The average nominal rental price of land over all farms and the entire sample was 831 FIM per hectare. The price increased from 400 to 1,400 FIM per hectare between 1976 and 1990, and thereafter, it had a downward sloping trend. In 1993 the average rental price was 1,130 FIM per hectare. The main trends in the purchase prices have been similar to those of the rental prices, but the purchase prices have been more volatile than the rental prices, partly because the data have substantially more leasing than trading transactions (Figure 6.2) [3].

The rental price over purchase price ratio is, on average, 0.049, suggesting an average 4.9 % discount factor if zero capital gains are expected. The ratio is consistent with the average real market interest rate (5.0 %), which will be characterized in section 6.6 below. Therefore, the annual average price of land ($Q_{l\,t}$) is computed simply as

$$Q_{l\,t} = (\text{Total Rent Payments FIM})_t / 0.049 * (\text{Total Hectares Leased})_t.$$

Note that the same price is used for all land. Thus, the price is exogenous for each farm and it measures average market prices of land.

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[3] The land trading transactions are discussed in the section on investments and capital accumulation.

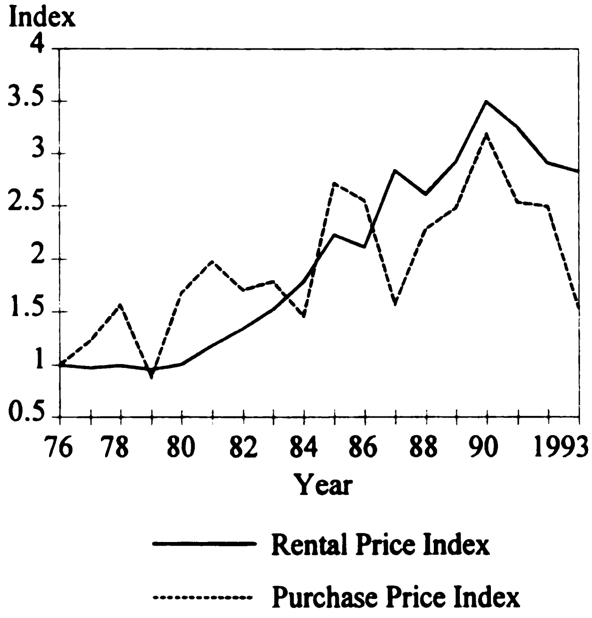

Figure 6.2. Rental and Purchase Price Indices for Land (Base Year =1976).

The Divisia Price Index for Real Estate

The price of land and the building price index are aggregated by the Divisia technique to obtain a price index for real estate. The building price index is computed by the Statistical Office and it is used for valuing both buildings and drainage systems. The Törnqvist approximation of the Divisia price index for real estate (Q_t) is computed as [4]:

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[4] For a detailed derivation of the index see e.g. Chambers (1988 pp. 232-239).

$$\log(Q_t/Q_{t-1}) = \frac{1}{2}\sum_{j=1}^{2}(S_{jt} + S_{jt-1})(\log q_{jt} - \log q_{jt-1}) \qquad (6.1)$$

$$\begin{aligned} \textit{where } Q_t &= \textit{Divisia price index at time } t \\ S_{jt} &= \textit{expenditure share of good } j \textit{ at time } t \\ q_{jt} &= \textit{price of good } j \textit{ at time } t \\ j &= \begin{cases} 1 \textit{ for land} \\ 2 \textit{ for buildings and drainage} \end{cases} \end{aligned}$$

The expenditures are computed as a sum of interest and depreciation. The average share of land expenditure in total real estate expenditure was 61.0 %.

6.1.2 Other Price Indices and Normalization

The price indices for machinery, feed, fertilizers, fuels, and electricity come from the index series of AERI. The price index for labor is computed by the Statistical Office. It follows the annual average wages paid to agricultural workers.

The feed, fertilizer, fuels, and electricity indices are aggregated to a Divisia price index for an aggregate variable input by using similar technique as above in the case of the price index for real estate (Equation 6.1). The variable input is used as a numéraire and all prices are normalized by this index. The normalized price indices are presented in Figure 6.3.

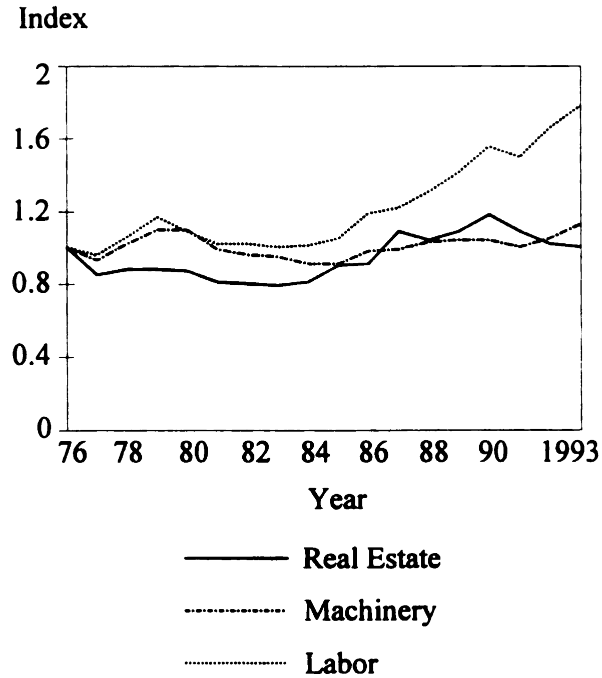

Figure 6.3. Normalized Price Indices for Real Estate, Machinery, and Labor (Base Year=1976).

6.2 Investments and Capital Accumulation

6.2.1 Real Estate

The accumulation of real estate was computed by farm in three steps:

1. The accumulation of the nominal values of the component goods (i.e. land, drainage, and buildings) were computed through their initial book values, investment expenditures, and depreciation. More specifically, the first observed balance sheet value of good j, $K_{j,t}^{n}$, for each farm was taken as a base value for

constructing the nominal series of the capital stock in the good j and, then, the value at the beginning of the following period, $K^n_{j,t+1}$, was computed through the transition equation:

$$K^n_{j,t+1} = I^n_{j,t} + (1-\delta_j)K^n_{j,t} \ , \ for\ j = 1,2,3 \qquad \textbf{(6.2)}$$

where $I^n_{j,t}$ stands for the nominal gross investment expenditure and δ_j is the depreciation rate. The resulting value of the good, $K^n_{j,t+1}$, was then used as the initial value for the next period.

2. The resulting values of the component goods were aggregated into a nominal value for real estate. Similarly, the investment expenditures of the component goods were aggregated into the expenditure on real estate investments.

3. The quantity indices of real estate and investments in real estate were obtained by dividing the nominal real estate values and the investment expenditures by the price index for real estate.

Land

Land and its accumulation are measured in terms of the capital stock in owned land. Leased land is excluded from the capital stock, because it is interpreted as a means of postponing investments in land, rather than as a long-term commitment that may be irreversible.

At the beginning of 1976 the average farm size in the sample was 29.8 hectares of arable land. On average, farms owned 23.9 and leased 5.92 hectares (Figure 6.4). The average areas purchased and sold over the study period were 6.22 and 0.260 hectares per farm, and so the average farm size increased by 5.96 hectares. Farms entering the bookkeeping program during the study period accounted for 1.68 hectares of the increase in the average farm size because entrants had more land than the exiting farms. At the end of 1993, the average farm size in the sample was 31.6 hectares of land owned and 5.65 hectares of land leased. The average land area owned in 1993 was 1.32 times the area owned in 1976.

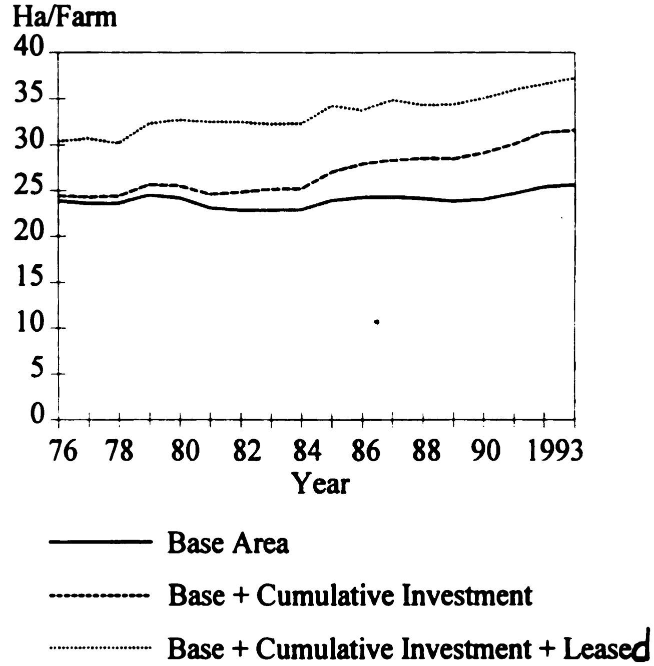

Figure 6.4. Land Accumulation on the Sample Farms.

The sample includes 135 land investment cases, which corresponds to about one investment per farm over the 18 years. The average investment size was 6.47 hectares. Land sales were less common than land purchases. Indeed, the sample has only 16 land sales cases. The average land area sold was 1.84 hectares, and only three sales exceeded two hectares in area. Areas of less than two hectares could have been traded without a permit for the purchase, and it is likely that they may have been bought for other than agricultural purposes, such as housing and recreation.

The average nominal price of land was 18,320 FIM per hectare for purchases and 34,050 FIM for sales. Hence, the price of land per hectare for sales was 1.9 times the price for purchases. The unplausible discrepancy between purchase and sales prices also supports the view that, in most cases, the land sold by farmers was bought for non-agricultural use. The observed prices suggest that we should use higher price for land sales than land purchases, but this would imply that farmers could profit infinitely by purchasing and selling land. Nevertheless, we rule out the possibility that farmers could profit infinitely by buying at the low price and selling land at the high price, and drop the rare land sales cases from the data.

Production Buildings

Accumulation of building capital was computed by transition Equation (6.2) as explained above. It is likely, however, that farmers have used depreciation primarily for adjusting and reducing their tax burden, and that observed depreciation is linked more to tax rates than to economic depreciation. Therefore, the observed depreciation is replaced by a constant geometric depreciation rate used in the national accounts of economic statistics. A building is assumed to have 10 percent of its initial value left after being used for 35 years, which implies a depreciation of 6.4 % a year; 2.5 percentage points lower than the average observed rate of 8.9 %.

At the beginning of 1976 the average value of production buildings was 50,600 FIM a farm, which inflated by the building cost index to the year 1993 equals 126,600 FIM. The average real gross investment expenditure was 19,600 FIM a year (in 1993 FIM). At the end of 1993 the average value of buildings was therefore 221,000 FIM, which is 1.75 times the inflated value for 1976.

The sample has 758 positive and 17 negative gross investments in buildings. The remaining 1,695 cases were zeros. Hence, an average sample farm invested in buildings 5.52 times over the 18-year period. The average compounded investment expenditure, within the positive gross investments, was 64,600 FIM.

Drainage Systems

The value of drainage systems and their accumulation is computed in a similar way as the accumulation of buildings, resulting in a depreciation rate of 6.4 % per year. The observed average depreciation rate was 13 %.

At the beginning of 1976 the average value of drainage was 7,680 FIM a farm, which equals 19,200 FIM when inflated to the year 1993 by the buildings price index. The average real gross investment expenditure was 3,670 FIM a year (in 1993 FIM). At the end of 1993 the average value of drainage was 38,600 FIM, which is 2.01 times the real value in 1976.

The sample has 378 positive and two negative gross investment cases, leaving 2,090 zero cases. An average sample farm invested in drainage 2.75 times over the 18-year study period. The average compounded investment expenditure, within the positive gross investment cases, was 24,300 FIM.

Real Estate

The land, building, and drainage were aggregated into a single capital good, real estate. The nominal values of this aggregate series was inflated by the price index of real estate. At the beginning of 1976 the average value of real estate was 819,000 FIM (in 1993 FIM). The average compounded gross investment expenditure was 33,600 FIM a year. At the end of 1993 the average value of the estate was 1,138,000 FIM, i.e. 1.39 times its inflated value in 1976. The annual averages of the inflated real estate values and investment expenditures are presented in Figure 6.5.

The sample has 1,066 positive and 17 negative cases of real estate investments (Table 6.1). The remaining 1,387 cases are zeros. An average sample farm invested in real estate 7.76 times during the 18-year period. The average compounded investment expenditure, within the positive gross investment cases, was 78,200 FIM. Nevertheless, the negative gross investments were dropped from the data, because the number was too small for a complete analysis, as suggested also by irreversibility of agricultural investments.

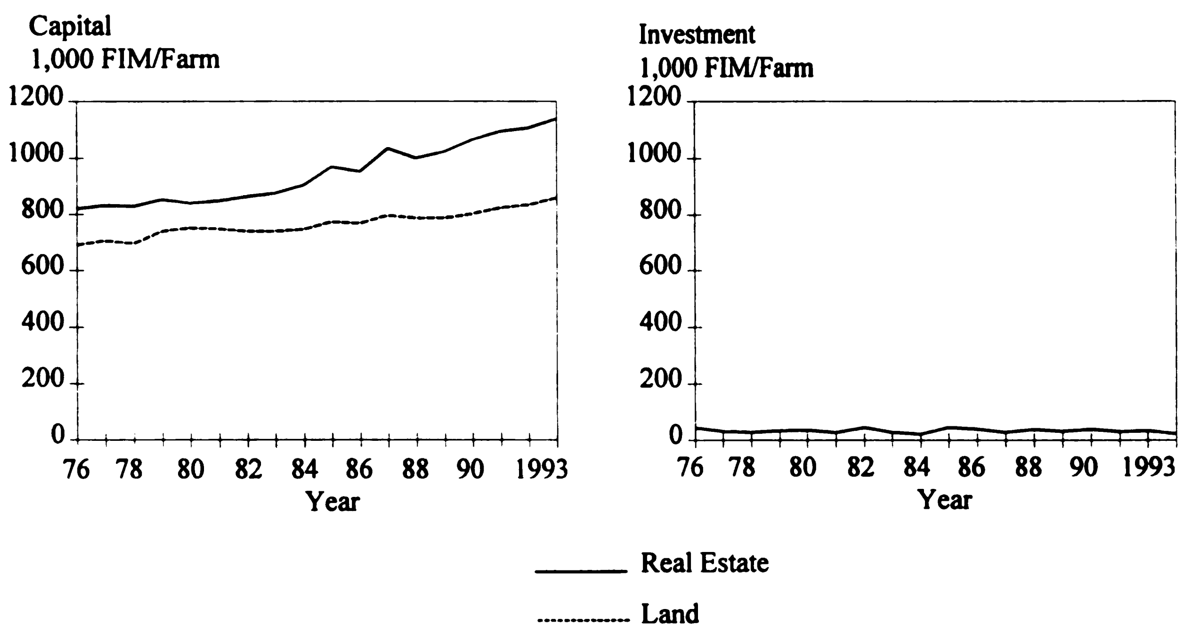

Figure 6.5. Accumulation of Real Estate Capital and Investment on Real Estate[5].

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[5] The series are inflated to the year 1993.

Table 6.1. Negative, Zero, and Positive Gross Investments.

Capital good	Number of negative cases	Average sales per case[a]	Number of zeros	Number of positive cases	Average investment per case[a]
Land	16	1.84 ha	2319	135	6.47 ha
Buildings	17	18,200 FIM	1,695	758	64,380 FIM
Drainage	2	7,857 FIM	2,090	378	24,330 FIM
Real estate	17	17,150 FIM	1,387	1,066	78,210 FIM
Machinery	29	37,620 FIM	483	1,958	87,370 FIM

[a] Inflated to the year 1993.

6.2.2 Machinery

Machinery capital and its accumulation are computed in a similar way as for buildings and drainage, except that a machine is assumed to have a shorter average economic life than a building. A machine is assumed to have 10 % of its initial value left after 15 years of use, which results in a 14 % depreciation a year. The observed average depreciation rate was 22 %.

At the beginning of 1976 the average value of machinery was 42,900 FIM a farm, which equals 132,000 FIM if inflated by the machinery cost index to the year 1993. The average real gross investment a year was 69,400 FIM (in 1993 FIM). At the end of 1993 the average value of machinery was 306,000 FIM, which is 2,32 times the compounded value in 1976 (Figure 6.6).

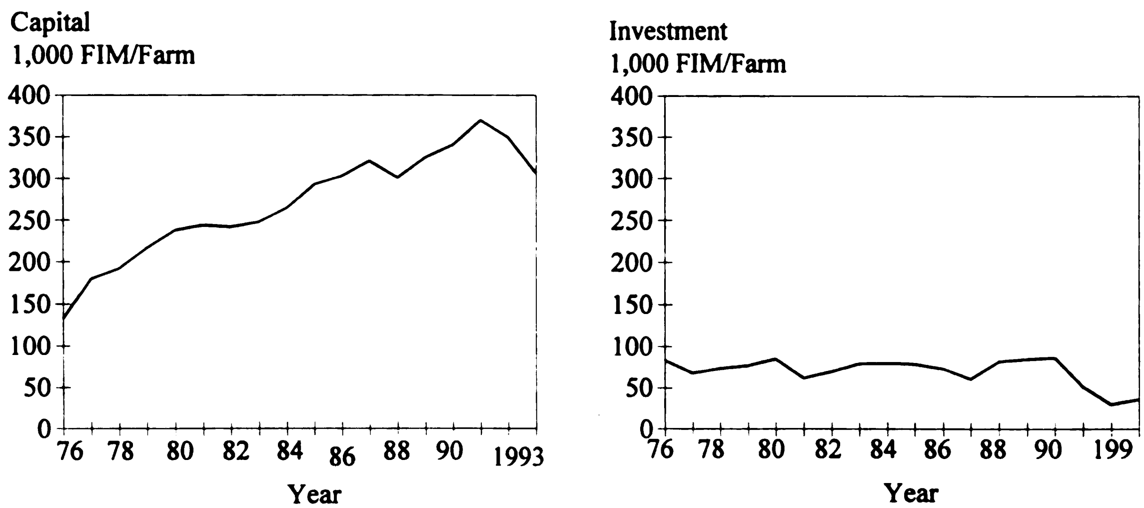

Figure 6.6. Accumulation of Machinery Capital and Investment in Machinery.

The sample has 1958 cases of positive and 29 cases of negative gross investments in machinery (Table 6.1). The remaining 483 cases are zeros. Hence, an average sample farm invested in machinery in four out of five years. The average real investment expenditure, within the positive gross investment cases, was 87,400 FIM. As before, the observations with negative gross investments were dropped from the data, because the number of them was too small for a complete statistical analysis.

6.3 Labor

The data on labor input are observed only as a service flow in terms of the hours of labor services. The data exclude stock measures, like the number of workers and employees hired. Therefore, labor and its changes are measured by annual labor services and changes in these each year.

The sample farms' average family labor input was 3,570 hours a year. They hired labor, on the average, 553 hours a year, which is 13.4 % of the total labor input. The average labor input had a downward sloping trend over the study period (Figure 6.7). The average decrease was 30 hours a year. The family labor input did not change much, but the hired labor input decreased by 38.3 % over the 18 years.

The measured changes in the labor input were not trapped at zero, because the labor input was measured as a service flow rather than a stock. The annual change in the labor input was negative in 1,105 cases and positive in 1,365 cases. Among the negative cases, the average reduction of the labor input was 482 hours. Among the positive cases, on the other hand, the average increase was 344 hours.

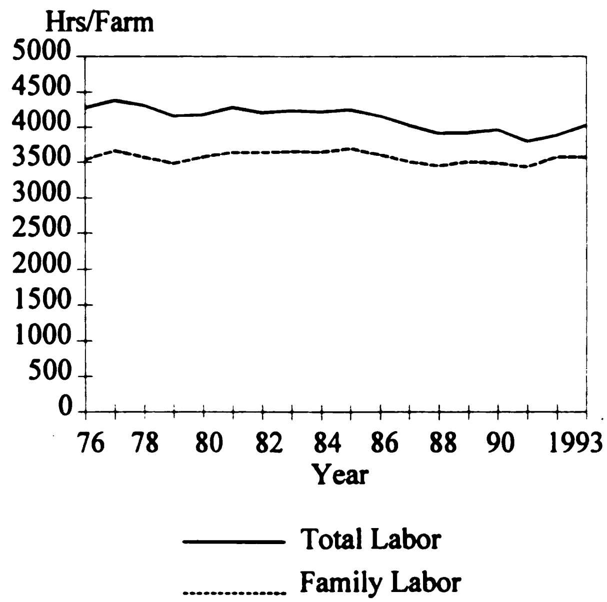

Figure 6.7. Labor Services on the Sample Farms.

6.4 The Numéraire Input

As explained above, the numéraire input is an aggregate of the four variable inputs, fertilizers, feed, fuels, and electricity. Again, the Divisia technique, similar to Equation (6.1), has been used for the aggregation. The resulting quantity index for the numéraire input is presented in Figure 6.8.

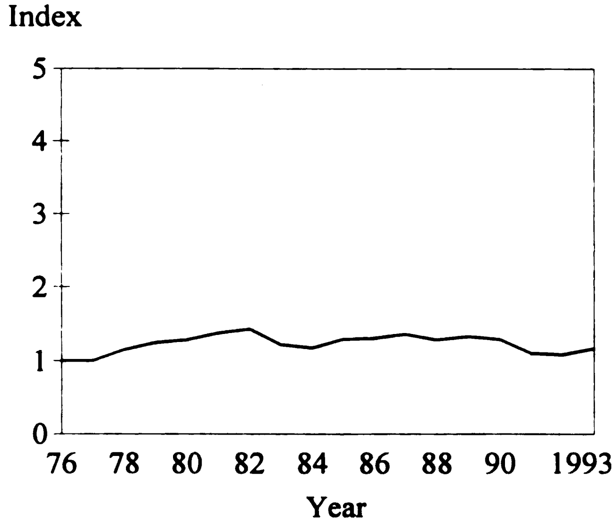

Figure 6.8. Index for Variable Inputs, Used as the Numéraire.

6.5 Output

The sample consists of specialized hog farms. The average shares of livestock and crop output in total agricultural revenue were 83 % and 13 %, which together accounted for 97 % of the total agricultural revenue (Table 6.2). Most livestock revenues were received from hog production. More specifically, the revenue share of pork, including piglets, was 95 % of livestock and 79 % of the total agricultural revenue. The crop revenue consisted mostly of (small) grains (67 %), and about half of the grain revenue came from barley.

Table 6.2. Average Revenue Shares in the Sample Farms.

Crops	% of crop revenue	% of total agricultural revenue[1]	Livestock	% of livestock revenue	% of total agricultural revenue[1]
Barley	33.5	4.1			
Rye	6.2	0.8	Pork	94.7	78.8
Wheat	9.9	1.5	Beef	1.4	1.3
Other grains	17.4	2.3	Milk	1.5	1.3
Oilseeds	6.0	0.8	Chickens	0.6	0.5
Sugarbeets	6.3	0.8			
Crops total	100	13.3	Livestock total	100	83.4

[1] Excluding income transfers.

The output data are measured and summarized by two output indices, one for livestock output and the other for crop output. The livestock output was computed for each individual sample farm in terms of pork equivalents, because pork accounted for the largest share of the livestock revenues. The total livestock revenue was divided by the price of pork, resulting in an index for the output quantity (pork equivalent). Similarly, the quantity of crop output was measured by barley equivalents. The total crop revenue was divided by the price of barley. Both livestock and crop outputs have an upward sloping trend (Figure 6.9). The crop output, however, has been more volatile than the livestock output, because of varying weather conditions.

The average livestock output is 42,000 pork equivalents, which roughly corresponds to a production unit with a 200 pig fattening capacity. The largest production unit in the sample is estimated to have a 1,300 pig fattening capacity.[6]

The output data were also summarized by a single output index, which was computed in terms of pork equivalents. The average value of the aggregate output is 49,000 pork equivalents.

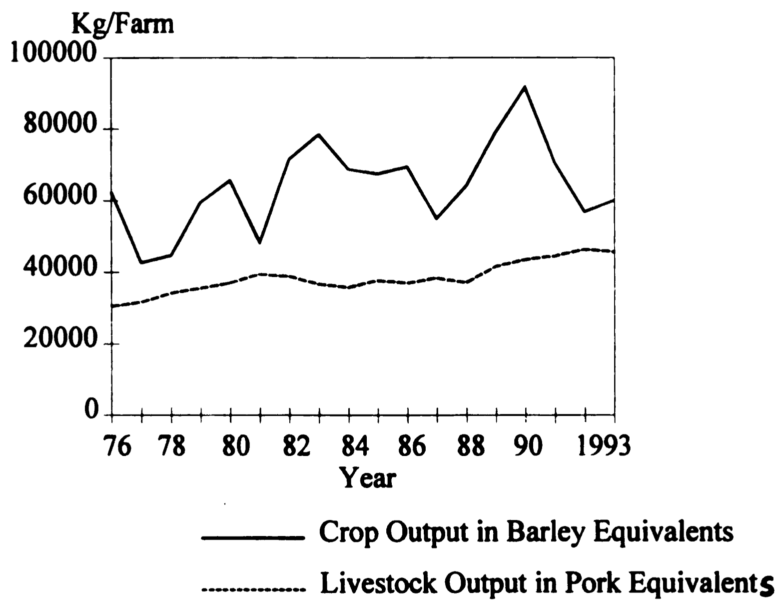

Figure 6.9. Crop and Livestock Output Indices.

[6] The fattening capacity is estimated from the livestock ouput index by assuming 74 kilograms carcass weight and four months period for fattening.

6.6 Credit Regimes and Discount Rate

The economic model given in Chapter 3 assumes perfect capital markets, but for studying the effects of the credit rationing we exogenously partition the sample into four regimes, as explained above. First, we partition the sample into two periods: (1) rationed years 1976-85 and (2) nonrationed years 1986-93. Then, we partition the sample into two groups: (a) nonrationed low-debt farms with $\frac{liabilities}{gross\ returns} < 0.9$ and (b) rationed high-debt farms with $\frac{liabilities}{gross\ returns} > 0.9$. It is likely that over the years 1986-93 the farms with low liabilities to gross returns ratios have been free from liquidity constraints.

Table 6.3 shows that the average investment on real estate does not differ much between the credit regimes. Machinery investment, on the other hand, differs between the regimes of low and high liabilities. The group averages suggest that, over the period of non regulated credit market, high liabilities may have been restricting machinery investments. Table 6.3 also reveals that the capital stocks are roughly constant but output levels differ across the low and high liability farms. In other words, farm capital has not been increasing along with production.

Table. 6.3. Farm Capital, Investments, and Output Stratified by Credit Regimes.

Regime	Real Estate [a]		Machinery [a]		Output [b]	L/R [c]
	Investment	Capital	Investment	Capital		
Rationed Market [d]	31.8	856	76.3	231	41.8	0.70
Rationed by L/R	32.6	945	66.8	239	30.6	1.27
Nonrationed by L/R	31.6	823	79.8	228	45.9	0.49
Nonrationed Market [d]	34.1	1,040	66.3	331	48.0	0.81
Rationed by L/R	35.3	1,120	54.4	303	38.0	1.41
Nonrationed by L/R	33.5	1,000	72.3	345	52.9	0.51
Full study period	33.1	962	70.6	288	45.3	0.76
Rationed by L/R	34.3	1,060	59.1	279	35.2	1.35
Nonrationed by L/R	32.6	920	75.7	292	49.8	0.50

[a] In FIM 1000 inflated to 1993.
[b] In 1000 pork equivalents.
[c] L/R= farm's total liabilities divided by gross returns. The farm is rationed by liabilities, if L/R>0.9. Otherwise nonrationed by liabilities.
[d] Over the years 1976-84 the credit market was rationed and thereafter nonrationed.

For discounting costs, we have used the real discount rate (r), which was computed from the nominal market interest rate (nr) and rate of inflation (infl) as (see Robison and Barry 1996, p.206):

$$(1 + nr) = (1 + r)(i + infl)$$

$$=> r = \frac{nr - infl}{1 + infl},$$

where the nominal rate is the annual average loan rate between 1976-86 and, thereafter, a 12 months HELsinki Inter Bank Offered Rate (12 months HELIBOR) minus 0.25. The HELIBOR series was adjusted to the average loan rate series by subtracting 0.25, which is the average difference between the two series over the period 1986-93. It would have been desirable to set the nominal rate to, say, a 12 months HELIBOR over the whole study period. But as explained in the preceding chapters, the credit market was rationed prior to 1986 and the 12 months HELIBOR was not recorded in the statistics until 1987.[7]

Inflation exceeded the nominal discount rate slightly in 1980 and 1981. Nevertheless, an inplausible negative real rate was ruled out by setting it to zero. The average real discount rate is about 5 %. The rate has an upward sloping trend until 1991 and a downward sloping trend thereafter (see Figure 6.10).

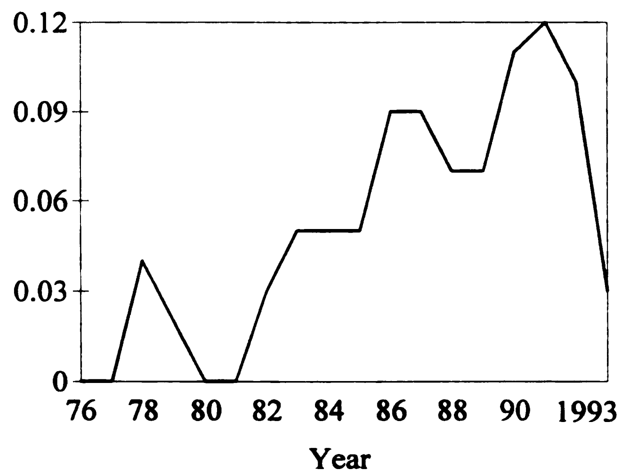

Figure 6.10. The Real Discount Rate.

[7] The market bond rates with 3 or 5 year maturities would have been preferred to the 12 months rate, but the 12 months rate was available earlier than the rates with longer maturity periods. The 12 months rate was also used by Pajuoja (1995).

6.7 Summary of the Farm Data

The observations with real estate capital less than 75,000, machinery capital less than 10,000, aggregate output less than 15,000, or labor less than 900 were dropped from the data, because it is likely that these extreme values have resulted from measurement errors. Summary Statistics for the resulting data set are presented in Table 6.4.

The data were rescaled to improve the estimation procedure so that all variables had approximately the same scale and weight in the optimization procedure. After scaling, the data are also consistent with the second order expansion of the optimal value function so that the variables get values around their expansion points. This also improves the flexibility of the optimal value function.

The price indices were rescaled to have value one in the year 1985. The output quantities and numéraire input were divided by their sample means. Real estate and machinery investments were divided by 75,000 FIM. For maintaining equal units of measurement, the same rescaling factor was used for rescaling the capital stocks, too. The labor changes were rescaled by the average reduction of labor services, conditional on negative change in the labor use. The labor services were rescaled by the same factor.

Table 6.4. Summary of the Farm Data.[a]

Variable	Mean	Standard deviation	Minimum	Maximum
Real estate capital	785,000	383,000	94,500	2,640,000
Investment on real estate	25,800	68,200	0	1,160,000
Machinery capital	219,000	136,000	10,100	741,000
Investment on machinery	51,500	59,700	0	380,000
Labor services	4,200	1,480	972	13,900
Change in labor services	-24.0	677	-3,030	4,080
Crop output	68,800	78,400	0	652,000
Livestock output	42,000	29,300	10,300	277,000
Variable input	281,000	197,000	36,100	1,460,000

[a] In 1993 prices.

Chapter 7

ESTIMATION RESULTS

The structural form parameters that appear in the optimal value function were estimated from the four decision rules using the FIML-technique, as outlined in Chapter 5. In particular, the loglikelihood function of the Tobit switching model was used. The model was estimated using the GAUSS Constrained Maximum Likelihood (CML) routine. The Davidon-Fletcher-Powell algorithm (DFP), which approximates the Hessian, was used to speed up initial iterations. Then, the Newton-Raphson algorithm, which computes the Hessian at every iteration, was used for obtaining the final model.

The feasible parameter space was reduced in several ways during the iterations because of the computationally intensive estimation procedure. First, the covariance matrix was constrained to be positive definite. But, as expected, this restriction was not binding in the converged models. Second, the optimal value function was restricted to be nondecreasing and concave in input prices. The inequality constraints imposing that the value function be nondecreasing in prices were not active in the final estimated model, but at least one out of the three concavity constraints were active in each of the estimated models.[1]

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[1] These concavity conditions equal the regularity conditions (D'.i) given in Chapter 4.

The original model specification had two output indices but it was so computationally intensive, and its log likelihood function was so flat around the maximum, that the model failed to converge and estimates could not be obtained. Instead we estimated an alternative model with only one aggregate output and informally checked this specification against the (unconverged) two output alternative. By comparing the log likelihood values of these two specifications it turned out that the fit of the model could not be significantly improved by splitting the aggregate output into crop and livestock components.[2]

Next, we tested for asymmetry in the adjustment rate matrix M. Depending on the model specified, the asymmetric model either did not improve the fit from that of the symmetric model, or the asymmetric model did not converge. Therefore, the symmetry of M could not be formally rejected. Hereafter, we continue to report and test the model with one aggregate output, and which maintains symmetry of the parameter matrices A, D, and M. We now move on to the estimation results in more detail by starting with the model estimated using the full sample. Then we test for misspecification of the model and report the results for several alternative model specifications. The chapter concludes with elasticity estimates and estimates for steady state capital stock and labor.

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[2] The likelihood ratio statistic for the test was 10.18, which is Chi-Squared distributed with nine degrees of freedom (χ^2_9), suggesting that the "one output model" should not be rejected in favor of "the two output model", because the test statistic was less than the critical value 16.92. However, this result has to be interpreted cautiously because the "two output model" did not converge.

7.1 The Full Sample Model

The parameter estimates for the full sample model are reported in Table 7.1. Although the reported full sample model converged, its loglikelihood function was so flat around the maximum that the Hessian was not invertible. There are no obvious ways to solve this problem. One way, however, is to isolate the parameters that are causing the trouble and compute the Hessian with these parameters fixed. In our case, the estimated covariance between the demand for labor and demand for the numéraire turned out to be negligible and insignificant (significance is reported later). This covariance was set to zero in order to obtain an invertible Hessian and standard errors for the other parameters. With this restriction, most of the estimates remained unchanged when compared to the estimates in the unrestricted model. Most of the parameter estimates differ significantly from zero at the 5 % two tailed significance level (Table 7.1)[3]. We discuss the definitions of these parameter estimates below.

[3] The 5 % two tailed significance level is used hereafter for testing null hypotheses, unless otherwise indicated.

Table 7.1. Estimation Results for the Full Sample Model. [a]

Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
a_{x0} [b]	1.0401	0.0281	H_1	0.2012	0.1636
			H_2	0.2756	0.2209
a_{11}	-0.0314	0.0127	H_3	-0.6735	0.1305
a_{12}	-0.7055	0.0815			
a_{13}	0.0505	0.0187	D_{11}	-0.2503	5.2113
			D_{21}	0.2100	2.2793
a_2	1.0746	0.1690	D_{22}	-1.9823	0.0000
			D_{31}	-0.3563	2.6454
a_{31}	-0.2172	4.2414	D_{32}	0.6326	2.5328
a_{32}	-0.8714	0.0000	D_{33}	-1.3302	1.8543
a_{33}	-1.0684	3.2047			
			M_{11}	0.1015	0.0067
A_{11}	-0.0012	0.0007	M_{21}	-0.0024	0.0036
A_{21}	0.0099	0.0019	M_{22}	0.0214	0.0000
A_{22}	0.0837	0.0131	M_{31}	0.0071	0.0048
A_{31}	0.0003	0.0006	M_{32}	-0.0104	0.0030
A_{32}	-0.0049	0.0033	M_{33}	0.1532	0.0060
A_{33}	-0.0025	0.0013			
			γ *for* $\dot{L}>0$	0.2076	0.0055
E_1	-0.0215	0.0089	$-\sigma^2_{q1}$	- 0.0257	0.0081
E_2	-0.3800	0.0707			
E_3	0.0351	0.0133	$-\sigma^2_{q2}$	- 0.1664	0.0104
			$-\sigma^2_{q3}$	- 0.0187	0.0071
B	0.9122	0.0504	bad year	0.0037	0.0214

[a] The number of observations is 1928, and the average value of the loglikelihood function is 1.224.

[b] An intercept in the demand equation for the numéraire input. It is a function of structural form parameters.

Bad year: a dummy variable for the years of crop damages in the demand equation for the numéraire.

Recall from Equation (4.7) that the structural form parameters presented in Table 7.1. appear in the optimal value function as:

$$J(K,Y,Q) = a_0 + a_1'K + a_2'lnY + a_3'lnQ + \frac{1}{2}K'AK + K'ElnY + \frac{1}{2}lnY'BlnY + lnY'HlnQ + \frac{1}{2}lnQ'DlnQ + Q'M^{-1}K$$

The last 5 parameters in Table 7.1 are dummy variables. Recall from Equation (4.11a) that

$$\dot{K} = Diag\{q_i^{-1}\} M\left(ra_3 + rH'lnY + rDlnQ\right)$$
$$+ (rU - (U + \gamma)M)K$$
$$- \frac{1}{2}\left[\sigma_{q1}^2 \quad \sigma_{q2}^2 \quad \sigma_{q3}^2\right]' \odot K$$

where the parameter γ has been used to model an adjustment rate for labor that is asymmetric, depending on whether the use of labor increases or not. Because the sample average for the labor change is negative, the base model has been estimated for negative changes and the dummy variable has been used to identify positive changes. The result suggests asymmetric labor adjustment and this result is discussed in more detail in subsequent sections.

The parameters σ_{q1}^2 ... σ_{q3}^2 are used for measuring the effects of a conjectured single persistent shift in uncertainty in 1991. They are parameters for dummy variables which have a value one over the years 1991-93 and zero otherwise. The parameter estimates are significant suggesting that increased volatility reduced, in particular, machinery investments. A dummy variable for exceptionally unfavorable harvest years was added to the demand equation of the numéraire input. This dummy variable has value one in the years of severe crop damages and zero otherwise. The parameter estimate for this dummy variable is denoted in Table 7.1 by "bad year", and it suggests that the demand for the numéraire decreases with crop damage. We shall examine the parameter estimates, as well as the price effects, output effects and adjustment rates, in more detail in subsequent sections.

The R-squared of the regression is 0.465 in the labor change equation, and 0.823 in the numéraire equation. In other words, the model explains 46.5 % of the variation in the changes in labor services and 82.3 % of the variation in the demand for the numéraire input. We now move on to the fit of the investment demands in more detail so that goodness of fit is measured by how well the model predicts the correct investment regimes within the sample.

If we take investment on real estate and measure it as a binary choice such that the choice is one for positive investment and zero for zero investment, the model predicts the indicator correctly in 1,059 out of 1,928 cases, and the probability of a correct prediction is 54.9 % (Table 7.2). The predictions have been computed so that the model predicts one if the estimated conditional probability for value one exceeds 0.5. Otherwise it predicts zero. Hence, the model predicts only 4.9 percentage points better than tossing a fair coin. Within the sample, the model over-predicts zero investment, predicting 1,581 zeros against an actual number of 1,062.

Table 7.2. Predicted and Observed Binary Investment Choices. [a]

		Predicted			
		Real estate investment		Machinery investment	
		0	1	0	1
Observed	0	887	175	1	346
	1	694	172	4	1,577

[a] The values 0 and 1 denote zero and positive investments.

The binary choice for machinery investment is predicted better than that for real estate investment. The model predicts the indicator correctly in 1,578 out of 1,928 cases in the sample, and the probability of a correct prediction is 81.8 %. Positive machinery investments are over-predicted in the sample. The model predicts 1,923 ones against 1,581 actually in the sample.

If we look at both binary choices together, the model predicts both of them correctly in 842 cases, and the probability of a correct prediction is 43.7 % (Table 7.3). The product of the two probabilities for individual choices (54.9 and 81.8 %) gives 44.9 % probability for predicting both of the variables correctly, whereas tossing a fair coin twice would give a correct prediction 25 % of the time. The model predicts best in the cases in which real estate investment is zero and machinery investment is positive, because within the sample that regime is over-predicted. The percentage of correct predictions in that regime is 68.4 %. In the other regimes, the model's capability to predict the observed outcomes is low. However, the model will not predict any cases in which real estate investment is positive and machinery investment is zero, because firms investing in real estate usually invest in machinery, too. But the model does not predict well the sample observations in which both investments are positive, or in which both investments are zeros. The low within sample predicting power of the model may be caused by farm specific individual effects, which we have not been able to control for.

Table 7.3. Observed Outcomes and Predictions in each Investment Category. [a]

Investment group	Number of observations	Number of predictions	Number of correct predictions	Percentage of the observations predicted correctly
$i_1 > 0$ and $i_2 > 0$ [b]	752	347	155	17.7
$i_1 > 0$ and $i_2 = 0$	114	0	0	0
$i_1 = 0$ and $i_2 > 0$	829	1576	686	68.4
$i_1 = 0$ and $i_2 = 0$	233	5	1	0.305
The full sample	1928	1928	842	43.7

[a] For a correct prediction we require that both investment choices (zero, one) are predicted correctly.
[b] i_1 and i_2 refer to the real estate and machinery investments.

7.2 Testing for Misspecification

7.2.1 Time Series Properties of the Price and Output Series

As explained in Chapter 4, the structural form parameters in the optimal decision rules are pinned down by the maintained hypothesis that output and prices follow a geometric Brownian motion without drift. Thus, it is important to test this hypothesis empirically to determine whether the assumption of geometric Brownian motion is appropriate in this application.

This section tests that the observed price and output series are geometric Brownian motion. A representative firm approach will be used, because it would be an overly onerous task to test each firms' series separately. Each output observation is constructed as an annual output average across the firms. The price data are normalized prices, as they appear in the decision rules. The series span 18 years. So we have 16 observations for estimating an AR(2) process. The tests are constructed for each univariate series separately.

We first define a second order autoregressive model for the scalar z_j as:

$$
\begin{aligned}
z_{jt} &= \mu_j + \psi_{j1} z_{jt-1} + \psi_{j2} z_{jt-2} + \varepsilon_{jt} \\
\text{where } E(\varepsilon_{jt}) &= 0 \\
E(\varepsilon_{jt}\varepsilon_{js}) &= \begin{cases} \sigma_j^2 & \text{for } t=s \\ 0 & \text{otherwise} \end{cases}
\end{aligned}
\qquad \textbf{(7.1)}
$$

which can be written in canonical form:

$$
\begin{aligned}
z_{jt} &= \mu_j + \rho_j z_{jt-1} + \xi_j \Delta z_{jt-1} + \varepsilon_{jt}, \\
\text{where } \rho_j &= \psi_{j1} + \psi_{j2} \\
\xi_j &= -\psi_{j2}
\end{aligned}
\qquad \textbf{(7.2)}
$$

Under the null hypothesis of geometric Brownian motion, μ_j=0, ξ_j=0, and 1-ψ_{j1}-ψ_{j2}=0, which also implies ρ_j =1. These conditions are stronger than implied by unit roots. A unit root in a univariate series would allow for nonzero ξ_j, while unit roots in multivariate setting would imply even more general conditions. To see this, stack the output and price series together (over j's) such that they define a vector valued AR(p) process with parameters μ, $\Psi_1 ... \Psi_p$, or the canonical form with parameters $\rho = \Psi_1 + ... + \Psi_p$ and $\xi_s = -(\Psi_{s+1} + ... + \Psi_p)$ for s=1,2,...,p-1. Then, in general, the unit roots and cointegrating vectors solve

$$|U - \Psi_1 - \Psi_2 - ... - \Psi_p| = |U - \rho| = 0,$$

in which the matrix U denotes an identity matrix. In other words, this condition implies that even though the z_j 's are nonstationary and integrated of order one, there is a long run relationship tying the individual series together, so that a nonzero linear combination of the z_j 's is stationary (Hamilton 1994). But, the special condition of unit roots included in our null hypothesis (i.e. ρ_j=1 for all j) is equivalent to the ρ=U which implies that the determinant of (U- ρ) equals zero, but not vice versa.

The single equation OLS estimates of (7.2) and their standard errors are presented in Table 7.4a. The term Δz_{jt-1} is included in the estimating equations for factoring out potential serial correlation in ε_{jt}, as suggested by the AR(2) process in (7.1). Regardless of the values of μ_j and ρ_j, the memory of the process, i.e. the null hypothesis ξ_j=0, can be tested by a standard t-test (Hamilton 1994). In every series, the null hypothesis ξ_j=0 is rejected at a 5 % two tailed significance level, suggesting the series follow an AR(1) process. Therefore, we continue simply by setting $\hat{\xi}_j = 0$ for all j. The parameter estimates with this restriction are presented in Table 7.4b.

Under the null hypothesis of $\rho_j = 1$, the estimates of ρ_j in are biased toward zero such that in 95 percent of the cases they are less than one (Hamilton 1994). In addition, neither $\hat{\mu}$ *nor* $\hat{\rho}$ exhibits a standard asymptotic distribution. Therefore, the Dickey-Fuller tests will be used for testing unit roots (Dickey and Fuller 1979). When choosing the test statistic we assume that the true process has a unit root without drift, that is, $\mu_j=0$ and $\rho_j=1$ for all j. The null hypothesis of a unit root ($\rho_j=1$) cannot be formally rejected in any series (Table 7.5). The joint hypothesis of a unit root without drift ($\rho_j=1$ and $\mu_j=0$) again cannot be rejected in any series.

Despite these test results it is possible that the machinery prices and output level are stationary, because the sample used for testing these series was very small and the tests have low power problems, particularly in small samples. Failure to reject the null hypothesis may also signal that the tested series are not informative about whether or not there is a unit root (Kwiatkowski et al. 1992). Nevertheless, we conclude that there does not seem to be very strong evidence against the null hypothesis, and so it is realistic to estimate the optimal decision rules under the assumption that prices and output follow geometric Brownian motion without drift. This result is also supported by Thjissen (1996).

Table 7.4a. OLS Estimates for the Output and Price Series of the Form (7.2).

	Parameter		
Series (z_j)[1]	Drift rate (μ_j)	Lagged level (ρ_j)	Lagged difference (ξ_j)[2]
Price of Real estate	0.0156 (0.0186)	0.844 (0.148)	0.0228 (0.237)
Price of machinery	0.0590 (0.0248)	0.483 (0.237)	0.458 (0.261)
Wages	0.0338 (0.0213)	1.03 (0.113)	0.0435 (0.301)
Output	0.0688 (0.0243)	0.774 (0.102)	0.166 (0.233)

[1] The series are in a logarithmic form. Standard errors are in the parentheses.
[2] The critical t-test value at 5 % two tailed risk level for the null $\xi_j=0$ is 2.16.

Table 7.4b. OLS Estimates for the Output and Price Series of the Form (7.2) with $\xi_j=0$.

	Parameter		
Series (z_j)[1]	Drift rate (μ_j)	Lagged level (ρ_j)	Lagged difference (ξ_j)
Price of Real estate	0.0155 (0.0179)	0.849 (0.135)	-
Price of machinery	0.0418 (0.682)	0.682 (0.223)	-
Wages	0.0342 (0.0203)	1.04 (0.0964)	-
Output	0.0705 (0.0237)	0.784 (0.0990)	-

[1] See Table 7.4a.

Table 7.5. The Dickey-Fuller and F-Test Statistics.

Series	Dickey-Fuller test[1] for $\rho_j=1$	F-test[2] for $\mu_j=0$ and $\rho_j=1$
Price of Real estate	-2.42	0.622
Price of Machinery	-5.09	1.02
Wages	0.588	0.0727
Output	-3.46	2.38

[1] The test statistics have been computed as $T(\hat{\rho} - 1)$ with T=16. The critical value at two tailed 5 % risk level with T=25 is -12.5. The critical values with less than 25 observations have not been tabled. The null is maintained, if the entry is greater than the critical value.
[2] The unrestricted versions have been run with Δz_j as the dependent variable. The critical value at two tailed 5 % risk level with T=25 is 5.18. The null is maintained, if the entry is less than the critical value.

6.3.2 Covariance Restrictions among the Error Terms

We have set the insignificant covariance between errors in the labor and numéraire input demand equations to zero in order to obtain the standard errors for the other parameter estimates. This restriction did not alter the other parameter estimates reported in Table 7.1. With no other restrictions among the errors in the decision rules, the lower triangular portion of the estimated covariance matrix is[4]:

$$\hat{\Sigma} = \begin{bmatrix} 2.54 & & & \\ 0.167^{*} & 0.561 & & \\ 0.164^{*} & 0.0377 & 1.66 & \\ -0.0838^{*} & -0.0337^{*} & 0 & 0.0880 \end{bmatrix},$$

[4] The unrestricted covariance between the labor and numéraire demand equations was insignificant, having value 0.0007.

which is, in terms of correlation coefficients,

$$\begin{bmatrix} 1 & & & \\ 0.140^{*} & 1 & & \\ 0.0805^{*} & 0.0388 & 1 & \\ -0.177^{*} & -0.152^{*} & 0 & 1 \end{bmatrix}$$

An asterisk in the entry denotes that the covariance differs from zero at the 5 % significance level. The significance of the covariances is tested by a Wald test. The test statistics for the null hypotheses that the covariance between ε_s and ε_j, for $s \neq j$ and $s,j=1,2,3,4$, equals zero is computed as (Hamilton 1994):

$$\sqrt{n}\frac{\hat{\sigma}_{sj}}{(\hat{\sigma}_s^2\hat{\sigma}_j^2 + \hat{\sigma}_{sj}^2)^{1/2}} \sim \textit{asymptotically } N(0,1)$$

where n is the number of observations in the sample

The resulting test statistics for zero entries in $\hat{\Sigma}$ are:

$$\begin{bmatrix} . & & & \\ 6.71 & . & & \\ 3.88 & 1.90 & . & \\ 8.45 & 7.26 & . & . \end{bmatrix}$$

If the entry exceeds 1.96, the corresponding covariance differs from zero at the 5 % significance level. The tests suggest that innovations in the real estate equation correlate positively with the innovations in the machinery investment and labor demand. The innovations in both investment equations are negatively correlated with the innovation in the demand for the numéraire input. Therefore, we can conclude that an equation by equation estimation procedure, or a system estimation with a diagonal covariance matrix, Σ, would have resulted in inefficient parameter estimates.

7.2.3 Liquidity Constraints and the Partition into Credit Regimes

To investigate whether liquidity constraints have been affecting the farmer's optimization behavior, we partition the sample exogenously into four regimes on the basis of two factors: (1) rationing in the credit market; and (2) firm liabilities relative to gross returns. It has to be noted, however, that we do not construct formal tests for the effects of the liquidity constraints in the original optimization problem. Rather, we check informally to see if our results are robust to partitioning the data by the factors that may have been driving up liquidity constraints (see e.g. Zeldes 1989).

We split the data into two time periods, a period of rationed credit market (1976-85) and a period of nonrationed credit market (1986-93). The observations over the period 1976-85 are more likely to be constrained by liquidity constraints than the observations after 1985. We further partitioned the sample over the years 1986-93 into a group of farms whose liabilities to gross returns ratio exceeds 0.9, and a group of farms whose liabilities to gross returns ratio is less than 0.9. We conjecture that, even though the credit market was deregulated, firms who had high liabilities to gross returns ratios may still have been liquidity constrained. The observations over the deregulated years 1986-93 which have low liabilities to gross returns ratios are, on the other hand, expected to be free from liquidity constraints.

The results suggest that a separate model should be run over the regulated (1976-85) and deregulated periods (1986-93). The likelihood ratio statistic for the full sample model as a null hypothesis against the two split models was 107.4. The test statistic exceeds the Chi-Squared 5% critical value with 48 degrees of freedom ($\chi^2_{48} = 64.89$), and the full sample model is rejected in favor of the two separate models in the split data. But even though there is a statistically significant difference between the models, there does not seem to be economically significant differences between the parameter estimates. The parameter estimates in the full sample model and in the partitioned sample models are almost identical (compare Table 7.1 and Appendix 1). We conclude that the credit rationing has had economically significant effects neither on the parameter estimates reported in Table 7.1 nor on investments. This result is also supported by Pajuoja (1995), who concluded that credit rationing has not had significant effects on farmer access to capital in Finland.

Next, we partitioned the deregulated period (1986-93) further into two subsamples representing the observations that meet different liabilities to gross returns ratios, as explained above. Although the regulated subsample model did not converge, the loglikelihood values reveal that the sample should be split and a separate model should be estimated for the different ratio categories. The likelihood ratio statistic for this test was 342, which clearly exceeds the critical value ($\chi^2_{48} = 64.89$) and the null hypothesis is rejected in favor of splitting the sample. In this case, the parameter estimates differ between the deregulated model (Table 7.6) and the full sample model reported above (Table 7.1). The subsample model, in which observations have high liabilities to gross returns ratio over the period 1986-93, is not reported because the model failed to converge.

Hereafter, we will report the results for the full sample model and for the model in the deregulated subsample, in which farm investments have been liquidity constrained neither by the credit market nor by liabilities. These models are referred to as "the full sample model" and "the deregulated subsample model".

Table 7.6. Estimation results for the Deregulated Subsample Model. [a]

Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
a_{x0} [b]	1.1251	0.0000	H_1	-0.0782	0.2503
			H_2	1.8745	0.6933
a_{11}	0.0350	0.0222	H_3	-1.5560	0.2544
a_{12}	-0.0782	0.1122			
a_{13}	0.0857	0.0362	D_{11}	-4.4395	0.0000
			D_{21}	2.4419	0.0000
a_2	1.4560	0.3693	D_{22}	-10.6005	0.0000
			D_{31}	-3.7782	4.4982
a_{31}	-4.2655		D_{32}	7.0961	1.6383
a_{32}	-0.7860	5.4498	D_{33}	-1.0956	0.0000
a_{33}	0.7892	1.7151			
		2.8040	M_{11}	0.1179	0.0088
A_{11}	-0.0040		M_{21}	-0.0225	0.0082
A_{21}	-0.0023	0.0016	M_{22}	0.0753	0.0244
A_{22}	0.0348	0.0030	M_{31}	0.0176	0.0060
A_{31}	0.0009	0.0195	M_{32}	0.0068	0.0062
A_{32}	-0.0115	0.0013	M_{33}	0.1800	0.0093
A_{33}	-0.0029	0.0053			
		0.0025	γ *for* $\dot{L}>0$	0.2062	0.0081
E_1	0.0267		$-\sigma^2_{q1}$	0.0081	0.0101
E_2	-0.1764	0.0133			
E_3	0.0776	0.0958	$-\sigma^2_{q2}$	-0.1139	0.0169
		0.0216	$-\sigma^2_{q3}$	0.0299	0.0085
B	0.9841				
		0.0804	bad year	-0.0462	0.0000

[a] The number of observations is 743, and the average value of the loglikelihood function is 0.9666.

[b] An intercept in the demand equation for the numéraire input. It is a function of structural form parameters.

7.2.4 Testing for Nonstandard Assumptions

In this section we examine whether the error terms in the estimated Tobit model meet the assumptions required for consistency of the parameter estimates. By nonstandard assumptions we mean nonnormality, heteroscedasticity, and serial correlation. The Tobit model is inconsistent if the normality or homoscedasticity assumption of the error terms is violated, but it remains consistent if the errors are serially correlated (Amemiya 1985). Therefore, it is important to check whether the normality and homoscedasticity assumptions are met in the model. Even though the Tobit model remains consistent if the error terms are serially correlated, it is also important to test whether the model is well-specified dynamically.

Tobit versus Probit Estimates

We do not construct a formal test for nonnormally distributed errors, but we check more generally the model specification by comparing the estimates between Probit and Tobit models, which are both run for the same decision rules. We can check whether the Tobit model is correctly specified by comparing the Tobit and Probit estimates, because it is unlikely that two different misspecified models would generate similar parameter estimates. Therefore, if there are wide discrepancies between the compared estimates either the normality assumption is violated or the specification is otherwise incorrect. If, on the other hand, the estimates are close to each other then it suggests the models are correctly specified.

Nevertheless, the Probit model can identify only the ratio between the parameters and the Standard Error (SE) of the error term in the estimated equation, say $\frac{\theta_{il}}{\sigma_1}$ (using the notation in Equation 5.1). Therefore, we mean by parameter estimates being "close to each other" that the estimates are close to each other up to a multiple. This multiple is one over the equation's SE (e.g. $\frac{1}{\sigma_1}$) estimated by the Tobit model.[5]

It turned out, however, that the Probit estimates are almost identical to those estimated by the Tobit model above. Without reporting the Probit results in more detail, we conclude that the Probit estimates do not reveal any mis-specification in the reported Tobit models.

Heteroscedasticity

Heteroscedasticity is first checked using simple auxiliary, or artificial, OLS-regressions run on logarithms of the squared error terms. Separate auxiliary regressions are run for each equation (denoted by j) amongst the four equations in (5.1).

These auxiliary regressions are rigorously valid under the null hypotheses of homoskedastic errors only in the uncensored equations, i.e. in the labor and numéraire equations. Thus, in these equations the auxiliary regressions are valid for making statistical inference on whether the null hypotheses are violated or whether they are not violated (e.g. Davidson and MacKinnon 1993).

But only the observations with positive investment can be used when explaining the logarithms of the error variances in the investment equations. Thus, these auxiliary

---

[5] In practice, we identified the Probit estimates by fixing the SE's at their Tobit estimates.

regressions are estimated conditional on positive investment. Therefore, the simple t- and F-tests on these auxiliary regressions are biased in favor of finding heteroskedasticity. Thus, there is tendency for the auxiliary regressions to suggest heteroskedasticity even if the original unconditional errors were homoskedastic.[6] Nevertheless, we estimate the full set of auxiliary regressions, and use these estimates as starting values for estimating the model under the alternative hypothesis of heteroskedasticity, then proceeding to a more formal Likelihood Ratio test for heteroskedasticity.

Under the alternative hypothesis, heteroskedasticity is assumed to be driven up by real estate capital, k_1, machinery capital, k_2, labor services, L, and by logarithm of output, lny, such that:

$$\ln(\hat{\varepsilon}_j^2) = \beta_{0j} + \beta_{1j}k_1 + \beta_{2j}k_2 + \beta_{3j}L + \beta_{4j}lny + v_j,$$

$$\begin{aligned} \textit{where } \hat{\varepsilon}_j &= \textit{predicted error in } (5.1) \textit{ for all } j = 1,2,3,4 \\ \beta_{sj} &= \textit{parameters for all } j \textit{ and for all } s=0,\dots,4 \\ v_j &= \textit{an i.i.d. error term for all } j \end{aligned}$$

The parameter estimates of these artificial regressions and their standard errors are reported in Tables 7.7a and 7.8a for the full sample model and for the deregulated subsample model. The estimation results infer significant heteroskedasticity in the labor and numeráire equations of both models. Heteroskedasticity may be a problem also in the investment equations. Therefore, we revise the estimated decision rules by correcting the

---

[6] By unconditional variance we mean that the variance is not conditioned on positive investment.

covariance matrix for heteroskedasticity. But to obtain a model that is feasible to estimate, the number of parameters in the equations which explain the variation in the variances of the error terms is decreased by dropping the insignificant parameters. Nevertheless, the same set of explanatory variables is used for correcting the heteroskedasticity in both investment equations. Estimation results from these auxiliary regressions when the insignificant variables have been dropped are reported in Tables 7.7b and 7.8b.

Next we corrected the estimation of the decision rules for heteroskedasticity as suggested by the artificial regressions in Tables 7.7b and 7.8b. However, all parameters of the revised model were re-estimated jointly by using the MLE-technique as before.

The heteroscedasticity corrected model in the deregulated subsample is reported in Table 7.9. The likelihood ratio statistic testing for the revised model against the null of the unrevised model (Table 7.6) is 354.2, which clearly exceeds the Chi-Squared 5% critical value with nine degrees of freedom ($\chi_9^2 = 16.92$). Therefore, the heteroscedasticity corrected version (Table 7.9) differs significantly from the model reported in Table 7.6.

The full sample model, on the other hand, either could not be improved, because a feasible step length was not found, or the model did not converge when it was corrected for heteroscedasticity. Hence, the revised full sample model is not reported.

Table 7.7a. Regressions on Logarithms of the Squared Errors in the Full Sample Model.[a]

	Investment/Demand Equation			
Variable	Real Estate	Machinery	Labor	Variable Input
Intercept	-1.81* [b] (0.293)	-3.22* (0.224)	-3.07* (0.195)	-3.97* (0.189)
Real Estate Capital, k_1	0.0204 (0.0212)	0.0113 (0.0165)	0.0144 (0.0143)	0.000922 (0.0138)
Machinery Capital, k_2	-0.154* (0.0559)	0.237* (0.0445)	-0.0210 (0.0384)	-0.0539 (0.0372)
Labor Services, L	0.125* (0.0205)	0.0239 (0.0167)	0.166* (0.0145)	0.0123 (0.0142)
Output, lny	0.660* (0.177)	0.289* (0.139)	-0.0949 (0.120)	1.70* (0.116)
R-squared	0.0685	0.0635	0.0682	0.154

[a] The model is reported in Table 7.1.

[b] An asterisk denotes significance at the two tailed 5 % risk level. Standard errors are in the parentheses.

Table 7.7b. Regressions on Logarithms of the Squared Errors in the Full Sample Model.[a]

	Investment/Demand Equation			
Variable	Real Estate	Machinery	Labor	Variable Input
Intercept	-1.69* [b] (0.266)	-3.16* (0.204)	-2.99* (0.154)	-4.00* (0.0501)
Real Estate Capital, k_1	.	.	.	.
Machinery Capital, k_2	-1.13* (0.0507)	0.249* (0.0405)	.	.
Labor services, L	0.125* (0.0205)	0.0262 (0.0163)	0.167* (0.0142)	.
Output, lny	0.724* (0.164)	0.326* (0.128)	.	1.62* (0.0867)
R-squared	0.0676	0.0632	0.0675	0.153

[a, b] See Table 7.7a.

Table 7.8a. Regressions on Logarithms of the Squared Errors in the Deregulated Subsample Model. [a]

	Investment/Demand Equation			
Variable	Real Estate	Machinery	Labor	Variable Input
Intercept	-1.86* [b] (0.460)	-3.98* (0.411)	-3.19* (0.326)	-3.73* (0.318)
Real Estate Capital, k_1	0.0273 (0.0308)	0.0389 (0.0292)	0.0459 (0.0327)	-0.00582 (0.0222)
Machinery Capital, k_2	-0.0571 (0.0693)	0.183* (0.0715)	-0.0847 (0.0558)	0.0129 (0.0546)
Labor Services, L	0.102* (0.0304)	0.0518 (0.0305)	0.165* (0.0245)	-0.0501 (0.0239)
Output, lny	0.374 (0.243)	0.436 (0.253)	-0.0760 (0.195)	1.65* (0.191)
R-squared	0.0472	0.0860	0.0603	0.172

[a] The model is reported in Table 7.6.

[b] An asterisk denotes significance at the two tailed 5 % risk level. Standard errors are in the parentheses.

Table 7.8b. Regressions on Logarithms of the Squared Errors in the Deregulated Subsample Model. [a]

	Investment/Demand Equation			
Variable	Real Estate	Machinery	Labor	Variable Input
Intercept	-1.62*[b] (0.370)	-3.72* (0.311)	-2.98* (0.254)	-3.75* (0.248)
Real Estate Capital, k_1	.	.	.	.
Machinery Capital, k_2	-0.0301 (0.0623)	0.220* (0.0660)	.	.
Labor Services, L	0.0992* (0.0302)	0.0551 (0.0305)	0.164* (0.0242)	-0.0499* (0.0236)
Output, lny	0.458* (0.224)	0.565* (0.234)	.	1.64* (0.134)
R-squared	0.0449	0.0832	0.0586	0.172

[a, b] See Table 7.8a.

Table 7.9. Heteroscedasticity Corrected Model in the Deregulated Subsample. [a]

Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
a_{x0} [b]	1.1877	0.0000	H_1	0.3161	0.3124
			H_2	0.5268	0.7494
a_{11}	0.0175	0.0247	H_3	-1.0291	0.2441
a_{12}	-0.1634	0.1202			
a_{13}	0.0325	0.0324	D_{11}	-6.6808	0.0000
			D_{21}	-1.0704	0.0000
a_{22}	0.9802	0.3519	D_{22}	-10.1852	0.0000
			D_{31}	0.7592	0.0000
a_{31}	-6.4631	0.0000	D_{32}	3.0413	23.1634
a_{32}	-5.9748	6.6877	D_{33}	-0.8468	0.0000
a_{33}	1.3705	6.1571			
			M_{11}	0.1172	0.0077
A_{11}	-0.0022	0.0017	M_{21}	-0.0223	0.0091
A_{21}	-0.0013	0.0034	M_{22}	0.0704	0.0275
A_{22}	0.0211	0.0209	M_{31}	0.0181	0.0042
A_{31}	0.0002	0.0013	M_{32}	0.0065	0.0058
A_{32}	-0.0022	0.0048	M_{33}	0.1840	0.0105
A_{33}	-0.0013	0.0021			
			γ *for* $\dot{L}>0$	0.2151	0.0084
E_1	0.0130	0.0156	$-\sigma^2_{q1}$	0.0048	0.0105
E_2	-0.1819	0.1038			
E_3	0.0286	0.0189	$-\sigma^2_{q2}$	-0.1174	0.0196
			$-\sigma^2_{q3}$	0.0153	0.0087
B	0.8006	0.0702	bad year	-0.0164	0.0000

[a] The number of observations is 743, and the average value of the loglikelihood function is 0.7001.

[b] An intercept in the demand equation for the numéraire input. It is a function of structural form parameters.

Serial Correlation

Serially correlated error terms are checked informally by a first order autoregressive model on the predicted error terms:

$$\hat{\varepsilon}_{j,t} = \beta_{j0} + \beta_{js}\hat{\varepsilon}_{s,t-1} + v_{j,t},$$

where $\hat{\varepsilon}_{j,t}$, $\hat{\varepsilon}_{s,t}$ *are predicted errors in* (5.1) *at time* t *for* $j, s = 1,2,3,4$
β_{hs} = *parameters for all* s *and for* h=0,1
$v_{j,t}$ = *an i.i.d. error term*

Again these auxiliary regressions are estimated for the investment equations conditional on positive investments and, therefore, they favor finding serial correlation. Nevertheless in the labor and numéraire equations the regressions are valid under the null hypothesis of no serial correlation in (5.1) i.e. $\beta_{1j}=0$ for j=3,4. Results from standard t- and F-tests in these two equations suggest that the errors are serially correlated. The innovation in the labor equation is negatively correlated with its own innovation lagged. And the innovation in the numéraire equation correlates positively with its own lagged innovation. There is also potential that the innovation in the real estate investment is positively correlated with the lagged innovation in the machinery investment, and vice versa.

The results suggest that the economic model is either dynamically incomplete or, alternatively, the decision rules are affected by significant farm specific effects. The latter result may follow because the artificial regressions were run in the pooled panel data and farm specific individual effects may have resulted in persistency in the values of the innovations across time.

However, we do not correct the estimation of the optimal decision rules for serial correlation. Serial correlation does not result in inconsistent estimates and the R-squareds in these artificial regressions are in most cases low although they favor serial correlation.

Table 7.10. Autoregressions on the Error Terms in the Full Sample Model (Table 7.1).

Variable	Investment/Demand Equation			
	Real Estate	Machinery	Labor	Variable Input
Intercept	1.02* [a]	0.157*	-0.169*	-0.0288*
	(0.0646)	(0.0266)	(0.0355)	(0.00710)
Lagged Error in the Equation for				
Real Estate	0.133*	0.075*	0.0246	0.0176*
	(0.0458)	(0.0207)	(0.0286)	(0.00573)
Machinery	0.150*	-0.0627*	0.0813*	0.0152*
	(0.0622)	(0.0270)	(0.0379)	(0.00758)
Labor	0.113*	0.0267	-0.0849*	-0.00169
	(0.0429)	(0.0190)	(0.0260)	(0.00521)
Variable Input	-0.0470	-0.0700	0.0196	0.559*
	(0.177)	(0.177)	(0.0997)	(0.0199)
R-squared	0.0378	0.0164	0.00910	0.329

[a] An asterisk denotes significance at the two tailed 5 % risk level. Standard errors are in the parentheses.

Table 7.11. Autoregressions on the Error Terms in the Deregulated Model (Table 7.6).

Variable	Investment/Demand Equation			
	Real Estate	Machinery	Labor	Variable Input
Intercept	0.967* [a]	0.546*	-0.0442	-0.00791
	(0.0777)	(0.0504)	(0.0568)	(0.0119)
Lagged Error in the Equation for				
Real Estate	0.104	0.172*	0.0800	0.0191
	(0.0648)	(0.0486)	(0.0589)	(0.0123)
Machinery	0.185*	0.0765	0.0726	0.0109
	(0.0863)	(0.0541)	(0.0654)	(0.0137)
Labor	0.0298	0.0426	-0.110*	-0.00932
	(0.0600)	(0.0414)	(0.0466)	(0.00974)
Variable Input	-0.213	-0.202	-0.0310	0.439*
	(0.255)	(0.150)	(0.174)	(0.0364)
R-squared	0.0419	0.0471	0.0153	0.216

[a] An asterisk denotes significance at the two tailed 5 % risk level. Standard errors are in the parentheses.

7.3 The Effects of Increased Uncertainty

As explained above we conjectured that, at the beginning of 1991 when the debate about Finland's joining the EU started, there was a one time persistent shift in uncertainty faced by Finnish farmers. This shift was measured by a dummy variable over the years 1991-93. The parameter estimates for this dummy variable are summarized for three model specifications in Table 7.12.

An increase in uncertainty either reduced or did not affect real estate investments. Machinery invesment, on the other hand, was clearly decreased by the prospect of joining the EU. The deregulated sample models also suggest that increased uncertainty increased the use of labor. Therefore, we conclude that less machinery was substituted for labor when uncertainty increased.

Table 7.12. Estimates for the Dummies over the Years 1991-93.

Decision rule for	Full Sample Model	Deregulated Subsample Model	Deregulated Subsample Model Corrected for Heteroskedasticity
Real Estate[a]	-0.0257*	0.0081	0.0048
	(0.0081)	(0.0101)	(0.0105)
Machinery[a]	-0.1664*	-0.1139*	-0.1174*
	(0.0104)	(0.0169)	(0.0196)
Labor[a]	-0.0187*	0.0299*	0.0153*
	(0.0071)	(0.0085)	(0.0087)

[a] When reporting the parameter estimates, these dummies have been denoted by $-\sigma^2_{q1}$, $-\sigma^2_{q2}$, *and* $-\sigma^2_{q3}$.

7.4 Adjustment Rates

As shown in Chapter 4, we can write the optimal decision rules in the flexible accelerator form. For all $\dot{k}_1>0$, $\dot{k}_2>0$, *and* $\dot{L}<0$ then $\gamma=0$ and we can write $\dot{K} = N(K - \bar{K})$, in which the matrix of adjustment rates is given by $N = rU - M$. Estimated adjustment rate matrices are reported in Table 7.13 for the full sample model, the deregulated subsample model, and the latter with a correction for heteroskedasticity.

Table 7.13. Estimates for the Adjustment Rate Matrices: $\hat{N} = \bar{r}U - \hat{M}$. [a]

Full Sample Model [b]	Deregulated Subsample Model	Deregulated Subsample Model Corrected for Heteroscedasticity
$\begin{bmatrix} -0.0525^{*} & & \\ 0.0024 & 0.0276^{*} & \\ -0.0071 & 0.0104^{*} & -0.1042^{*} \end{bmatrix}$	$\begin{bmatrix} -0.0689^{*} & & \\ 0.0225^{*} & -0.0263^{*} & \\ -0.0176^{*} & -0.0068 & -0.131^{*} \end{bmatrix}$	$\begin{bmatrix} -0.0680^{*} & & \\ 0.0223^{*} & -0.0214^{*} & \\ -0.0181^{*} & -0.0065 & -0.135^{*} \end{bmatrix}$

[a] The adjustment rates have been computed for $\bar{r}=0.049$, $\dot{k}_1>0$, $\dot{k}_2>0$, *and* $\dot{L}<0$. The corresponding models are reported in Tables 7.1, 7.6, and 7.9.

[b] An asterisk, if it is attached to a diagonal entry, denotes the entry is greater than -1 at the 5 % one sided risk level. If the asterisk is attached to an off-diagonal entry, it denotes the entry differs from zero at the 5 % two sided risk level.

The adjustment rates are more plausible in the deregulated subsample models than in the full sample model, as expected. All diagonal entries in $\hat{N}$ have plausible negative signs in the deregulated sample, and most of the entries in $\hat{N}$ have larger magnitudes in the deregulated sample than in the full sample model. Heteroscedasticity seems to have only negligible effects on the adjustment rate estimates, as the estimates are insensitive with respect to the correction for heteroscedasticity.

Null hypotheses about the adjustment rates have usually been constructed as:

(1) The j^{th} good in K adjusts instantaneously, i.e. it is a variable input. Under the null, the j^{th} diagonal element of N equals -1 and, in addition, its off-diagonal elements in the j^{th} row are zeros. If this holds for all goods in K, the matrix N equals the identity matrix multiplied by minus one.

(2) The adjustment of the j^{th} good in K is independent of disequilibrium in the market of the other goods. Under the null, the off-diagonal elements in the j^{th} row of N are zeros. If this holds for all goods in K, then N is diagonal.

(3) The adjustment rates are symmetric; N is symmetric.

We add a fourth null hypothesis:

(4) The adjustment of labor is symmetric with respect to changes in the labor services (γ=0).

When testing the parameters individually, the first null hypothesis, which assumes instantaneous and independent adjustment, is rejected for all goods, because all diagonal elements of $\hat{N}$ are significantly greater than -1. The second hypothesis assuming independent adjustment is also rejected, because at least one off-diagonal element in $\hat{N}$ differs significantly from zero in every specification. The third null hypothesis, stating that N is symmetric, is maintained without testing, because the models with asymmetric M failed to converge. The fourth null hypothesis, which conjectures symmetric labor adjustment with respect to changes in labor services, is rejected as well. The dummy variable used for modeling asymmetry in the labor adjustment was estimated significantly in every specified model. Depending on the specification, the third diagonal element in $\hat{N}$ for positive labor changes is either 0.103, 0.0705 or 0.0801. Each of these estimates is significantly greater than -1, suggesting that labor services increase sluggishly.[7]

We conclude that real estate, machinery and labor are quasi-fixed in the sense that they adjust sluggishly to the shocks in the exogenous state variables. All three goods are subject to adjustment costs. In addition, the adjustment of each good depends on

[7] We have used one sided test at 5 % significance level. The critical value is 1.645.

discrepancy between the current and steady states of at least one of the other goods, and labor adjustment is asymmetric depending on whether labor services are decreasing or increasing. We now turn to the adjustment rates in more detail.

Real estate

The adjustment rate of real estate with respect to the discrepancy between its own current and steady states has a plausible sign in every model specification, and the adjustment rate has a larger magnitude in the deregulated subsample than in the full sample. In the deregulated subsample the estimated adjustment rate is -0.07, suggesting that real estate capital converges to a steady state equilibrium but it adjusts slowly towards the equilibrium. For example, over a five- year period, the response to an initial shock will decrease the discrepancy between the actual and the steady state capital by 30 %.

The adjustment rate of real estate with respect to the discrepancy between machinery's current and steady states is significant and positive, suggesting intertemporal complementarity between real estate and machinery. In other words, the result suggests that real estate investment is increasing in machinery and, similarly, machinery investment is increasing in real estate.[8] Thus, excess machinery drives real estate investment up, and vice versa. This complementarity between real estate and machinery implies that, for example, excess machinery can be utilized more efficiently by purchasing more real estate. Similarly, excess real estate can be employed more efficiently by investing more in machinery.

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[8] Recall that we have maintained symmetry of the adjustment rate matrix.

The result that capital goods are complements is interesting because numerous empirical investment studies use aggregated capital and, therefore, make an implicit assumption that capital goods are perfect substitutes for each other. In the light of our results, on the other hand, aggregating real estate and machinery into a single capital good is not justified.

The adjustment rate of real estate with respect to the discrepancy between the current and steady state labor is significant and negative. The result suggests that labor and real estate are short-run substitutes so that excess labor, for example, decreases real estate investment. In other words, farm's excess labor is employed in the short run by delaying substitution of capital for labor.

Machinery

The estimated adjustment rate of machinery with respect to the discrepancy between its own current and steady states is positive in the full sample and negative in the deregulated subsample. This suggests that farmers' access to machinery capital may have been restricted by liquidity constraints. Even though the adjustment rate is negative in the deregulated subsample, its magnitude is small (-0.03), suggesting that machinery capital adjusts very slowly towards its steady state level. A discrepancy between the observed and steady state capital stock will shrink over a five-year period by only 14 %. We would expect a faster machinery adjustment, and this sluggish investment behavior may signal significant farm specific individual effects, which are time constant but vary across individual farmers. It is likely, as the shadow prices reported below will suggest, that the unobserved individual effects have been driven up by individual tastes. Some farmers have preferred modern to old equipment, which has resulted in excess machinery capital[9]. Alternatively, additional incentives to invest in machinery have been provided by successive tax shields generated by the difference between the economic and tax depreciations.

Investment in machinery is independent of the discrepancy between the current and steady state labor. Symmetry of the adjustment matrix implies also that changes in labor services are independent of the discrepancy between the current and steady state machinery. This result is somewhat surprising because we would expect that machinery and labor are substitutes even in the short run so that, for example, a shortage in the firm's labor would trigger the firm to invest more in machinery and labor saving technologies. Nevertheless, the elasticity estimates reported below support our expectations.

Labor

Around the sample mean, the change in the labor services is negative with an adjustment rate estimated at -0.13. Thus, labor services converge and a discrepancy between the firms current and steady state labor is reduced by 50 % over a five-year period. Labor adjusts asymmetrically so that increases in labor services are even more sluggish than decreases in labor services. This result is supported also by Oude Lansink (1996). However, the adjustment rate for labor increases is positive at 0.08, suggesting that there is no convergent

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[9] I.e. we have unobserved time constant individual effects, which we have not been able to control for.

path for labor services in the regime of positive labor changes. Or, more importantly, the result suggests that farmer's access to short-term hiring contracts as an employer is restricted. In other words, the result supports the view that when more labor is needed in the short run, it is not available or, alternatively, the labor market is inflexible with regard to short-term hiring contracts.

7.5 Shadow Prices for Installed Capital and Labor

Recall the consistency conditions (B.ii) in Chapter 4, which conjectured that the shadow price for installed capital is negative if the firm is investing and positive if the firm is disinvesting. In other words, the optimal value function (the discounted present value of the cost stream) is expected to be decreasing in the capital stock when the firm is investing and increasing in the capital stock when the firm is disinvesting. With zero investment, the shadow price can be either negative or positive, but between the shadow prices of the investing and disinvesting firms. Because the approximation to the optimal value function holds only around the sample averages, we correspondingly test the shadow prices around the sample means only. From the conditions (B.ii) we construct the following null hypotheses:

(1) The shadow prices of real estate and machinery, evaluated around the sample means of the state variables, are negative, because the average observed investment is positive.

(2) The shadow price of labor, evaluated at the sample means of the state variables, is positive, because the average change in the labor services is negative.

The estimated shadow prices for both capital goods differ significantly from zero, but they are positive, having opposite signs to what we expected (Table 7.14). The null hypotheses in (1) are therefore rejected and we conclude that the data does not support the view that the optimal value function is decreasing in real estate and machinery capital. This result suggests that the discounted present value of the firm's cost stream is expected to increase, if its capital stock is increased ceteris paribus.

Because real estate and machinery are both measured in equal units, their shadow prices should be equal at the margin, provided farmers have had equal access to both capital goods. But given the small standard errors of the shadow price estimates, it is obvious that the difference between the prices is statistically significant. Indeed, the shadow price of machinery is about one third larger than the shadow price for real estate. If there were internal adjustment costs only, firms could have reduced their costs by equating shadow prices across the capital goods. In other words, they could have decreased costs at the margin by delaying the machinery investments and by investing only in real estate until the marginal benefit from a unit of capital became equal across the goods. The large difference between the shadow prices cannot be explained by internal adjustment costs. Therefore, the result suggests that farmers have not had equal access to both capital goods or, more likely, they have had external incentives for investing in machinery. Farmers have been more eager to invest in machinery than in real estate either by tastes, or because of higher incentives through tax shields.

Using the equality $\partial C/\partial i_j = -\partial J/\partial k_j \; for \; j = 1,2$, the estimated shadow prices imply that adjustment costs exist, but the instantaneous cost function is decreasing with investments, i.e. $\partial C/\partial i_j < 0 \; for \; i_j \geq 0, \; j = 1,2$. This result supports the view that there are scale effects in investment, such that the larger the investment the smaller the adjustment costs that are realized. This result is plausible, but it contradicts the traditional postulate that adjustment costs are increasing and convex in investment. Our result is also supported by Rothschild (1971), who claims that the arguments for cost functions being increasing in investment are weak. It has to be noted, however, that the result obtained does not meet the sufficient conditions for an extremum in the original maximization problem. We rely, therefore, on the necessary conditions.

Even though the shadow price of installed real estate capital is positive, the instantaneous cost function is decreasing in real estate (Table 7.15). This result suggests that the cost of investing, including adjustment costs, has outweighed the cost reductions resulting from the increased capital stock. Investments in machinery, on the other hand, have not even reduced the instantaneous costs.

Table 7.14. Shadow Prices for Installed Capital and Labor. [a]

Good	Full Sample Model	Deregulated Subsample Model	Deregulated Subsample Model Corrected for Heteroskedasticity
Real Estate [b]	10.4	11.0	11.3
	(3.16)	(0.00)	(n.a.)
Machinery [b]	52.0	16.1	17.3
	(1.05)	(0.00)	(n.a.)
Labor [c]	9.62	3.91	3.73
	(1.10)	(1.03)	(n.a.)

[a] The shadow prices are elements of the gradient $\nabla_K J' = a_1 + AK + ElnY + M^{-1}Q$, and they are evaluated at sample means. Standard errors are in parentheses.
[b] The sample average of gross investment is positive.
[c] The sample average of change in the labor services is negative.
n.a. refers to "not available".

Table 7.15. Derivatives of the Instantaneous Cost Function with respect to Capital and Labor. [a]

Good	Full Sample Model	Deregulated Subsample Model	Deregulated Subsample Model Corrected for Heteroskedasticity
Real Estate [b]	-0.310	-0.271	-0.252
	(0.210)	(0.00)	(n.a.)
Machinery [b]	8.83	2.04	2.27
	(0.198)	(0.00)	(n.a.)
Labor [c]	-0.529	-0.809	-0.817
	(0.0539)	(0.0505)	(n.a.)

[a] The derivatives are computed as $\nabla_K C' = (r + \delta)\odot\nabla_K J' - Q - A(I - \delta K)$, and they are evaluated at sample means and at I=δK.
[b, c] n.a. See notes in Table 7.14.

The shadow price of labor is positive and significant, as expected, and the null hypothesis (2) is supported by the data. The optimal value function is increasing in labor even though the instantaneous cost function is decreasing in labor (see Tables 7.14 and

7.15). In other words, the sum of expenses, including adjustment costs, to purchase more labor services has exceeded the sum of instantaneous cost reductions provided by increased labor. Net returns to incremental labor services have been negative, and firms have been gradually substituting capital for labor to decrease costs. Further, had the firms been able to reduce their labor input even more, they would have been able to reduce their production costs, ceteris paribus.

Again, using the conditions in (B.ii) and, in particular, the equality $\partial C / \partial \dot{L} = -\partial J / \partial L$, we conclude that the instantaneous cost function is decreasing in changes of labor, i.e. $\partial C / \partial \dot{L} < 0$ *for* $\dot{L} < 0$, as expected. Note that, as the average labor change is negative, this result implies that the cost function is increasing in the absolute value of the labor change.

In summary we conclude that, even though instantaneous costs have been decreasing with one out of two capital goods, and with labor services, the sample farms have had excess capital and labor relative to their output levels. At a given output level they could have reduced the discounted present value of their production costs by reducing the capital stock and labor.

7.6 Short-Run Response Probabilities and Elasticities

Response Probabilities

We measure response probabilities by how many percentage points the probability of a positive investment is predicted to change, if an explanatory variable is changed, ceteris paribus, by one percentage point. In other words, we have rescaled capital stocks and labor services so that a one unit change corresponds to a one percentage unit change in the original untransformed variables around their mean values. Because output and price indices are in a logarithmic form, a one unit change in them corresponds to a one percentage point change in the original untransformed variable. Estimated response probabilities for real estate and machinery investments in the deregulated subsample model, which is corrected for heteroskedasticity, are reported in Table 7.16. [10]

The response probabilities for positive investments with respect to output have plausible positive signs, but their magnitudes are negligible. Even though the probability of investing is increasing with output, it is insensitive to changes in output. This result is consistent with the results above, suggesting that farms have had excess capital. Thus, increased output has resulted in more intensive use and more efficient utilization of existing capital, but it has not necessarily driven up investments. Further, the result suggests that there are significant scale economies in utilizing the capital stock.

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[10] To reduce the number of tables in the text, the short-run response probabilities and elasticities are reported here only for the deregulated subsample model, which is corrected for heteroskedasticity. The results of the other two model specifications are given in Appendix B.

Most of the price effects have plausible signs. For example, negative own price effects suggest that investments have been decreasing with their own prices, as expected. However, the magnitudes of the price effects are negligible, suggesting that investments have not been sensitive to prices. These results may signal that under fairly restrictive production controls then prices have not been dominant factors in determining investments.

The physical level of firms' capital and labor services have played a more important role in determining investments than the prices and the level of output. A ten percent unit increase in the farm's real estate capital, for example, has reduced its probability to invest in real estate about two percentage units. The probability of investing in real estate has been decreasing in the firm's actual real estate capital and labor services but increasing in machinery capital. In other words, excess real estate capital and labor has driven real estate investments down, but excess machinery capital has driven real estate investment up. This result suggests that, in the short run, real estate and machinery capital have been complements, but real estate and labor services have been substitutes.

Gross investments in machinery have been increasing in the firm's actual machinery capital, because machinery depreciates and large replacement investments are required to maintain a capital stock of machinery. But still, the probability of a positive net investment in machinery has been decreasing with the actual machinery capital stock, as expected. Excess machinery capital has, in other words, been driving net investment in machinery down. Machinery investment has also been decreasing in labor services, which suggests that machinery and labor have been substitutes in the short run. Excess real estate capital has, on the other hand, been driving machinery investment up. This result again implies that machinery and real estate have been short-run complements, as explained above. It has to be noted, however, that we have maintained symmetry of the adjustment matrix resulting in sign-symmetric elasticities between capital stocks and labor.

Table 7.16. Response Probabilities for Positive Investments.

With respect to	Real estate		Machinery	
	gross investment	net investment	gross investment	net investment
Log of output	0.00010	0.000089	0.000352	0.000417
Log of prices:				
real estate	-0.00192	-0.00170	0.00119	0.00140
machinery	-0.00236	0.00209	-0.00576	-0.00682
wage rate	0.000086	0.000076	0.00289	0.00342
Capital[a]				
real estate	-0.166	-0.196	0.0755	0.0894
machinery	0.0192	0.0170	0.106	-0.0226
Labor[b]	-0.0584	-0.0517	-0.0217	-0.0257

[a] A one percentage change around the sample average. The sample averages are 754,000 and 199,000 FIM.
[b] A one percentage change around the sample average. The sample average is 4,090 hours.

Elasticities

We define two kinds of elasticities: conditional elasticities and unconditional elasticities. Conditional elasticity is conditioned on the exogenous state variables and, in addition, on positive gross investment. The unconditional elasticity is conditioned on the exogenous state variables, only. Elasticity estimates are presented in Tables 7.17 and 7.18.

As above in the case of the response probabilities, output and price elasticities have plausible signs in the sense that output and cross price elasticities are positive, but own price elasticities are negative. The magnitudes of these elasticities are, nevertheless, negligible. We conclude that investments have been inelastic with respect to the output level and prices. Again, the unplausibly low output elasticities may result from the stringent production controls that have influenced the connection between output changes and the level of investments. The observed range of output fluctuations may have resulted primarily in marginal adjustments of intensity in capital use, rather than lumpy investments. This phenomenon is also supported by the result that farms have been in excess capital relative to their output levels. Nevertheless, low unconditional output elasticities are consistent with significant economies of scale.

Unconditional elasticities of real estate, in particular, with respect to capital stocks and labor services are clearly larger in magnitude than the corresponding conditional elasticities. This suggests that the combined effects of a regime shift (from zero to positive investment) and an increase in investment size are important in measuring elasticities of real estate investments, whereas either one of these two responses alone shows relatively inelastic effects.

Real estate investment is decreasing and elastic with respect to its own capital stock. Elasticity estimates confirm, again, that real estate investments are increasing considerably in excess machinery but decreasing in excess labor. In other words, elasticities show substantial short-run complementarity between real estate and machinery but short-run substitutability between real estate and labor as above.

The differences between the conditional and unconditional elasticities are not as large in machinery investments as in real estate investments, partly because the number of zero machinery investments in the data is small. The elasticity estimates in Table 7.18 show notable increase in the gross investment in machinery with respect to the increases in machinery capital. Net investment in machinery is, however, slightly decreasing with its own capital, as before. In addition, the elasticities show that machinery investment is increasing substantially with excess real estate capital, again signaling strong complementarity between real estate and machinery. Labor and machinery are, however, short-run substitutes, as excess labor will decrease machinery investments and slow down substitution of labor saving technologies for labor. It has not paid, for example, to invest in advanced feeding technologies if there has not been any alternative demand and income sources for the saved labor input.

Table 7.17. Short-Run Elasticities for Real Estate Investments.[a]

With respect to	Gross investment		Net investment	
	conditional[b]	unconditional[c]	conditional[b]	unconditional[c]
Output	0.000122	0.000509	0.000118	0.000544
Prices:				
real estate	-0.00233	-0.00976	-0.00226	-0.0104
machinery	0.00287	0.0120	0.00278	0.0128
wage rate	0.000105	0.000439	0.000102	0.000470
Capital:				
real estate	-0.202	-0.843	-0.260	-1.20
machinery	0.0233	0.0975	0.0226	0.104
Labor	-0.0710	-0.297	-0.0687	-0.318

[a] Elasticities are evaluated at the sample means.
[b] Expected investment is conditioned on the predetermined state variables and on positive gross investment.
[c] Expected investment is conditioned on the predetermined state variables only.

Table 7.18. Short-Run Elasticities for Machinery Investments.[a]

With respect to	Gross investment		Net investment	
	conditional[b]	unconditional[c]	conditional[b]	unconditional[c]
Output	0.000693	0.00118	0.000659	0.00144
Prices:				
real estate	0.00234	0.00398	0.00222	0.00486
machinery	-0.0113	-0.0193	-0.0108	-0.0236
wage rate	0.00569	0.00970	0.00541	0.0118
Capital:				
real estate	0.149	0.254	0.141	0.310
machinery	0.208	0.355	-0.0358	-0.0783
Labor	-0.0428	-0.0730	-0.0407	-0.0891

[a, b, c] See notes in Table 7.16.

Changes in labor services are decreasing (becoming more negative), but inelastically, with the output and the wage rate in the short run (Table 7.19). The short-run response of labor with respect to the other prices is also negligible. The results suggest, however, that labor services are decreasing with excess capital and, in particular, with excess real estate. Further, labor services are decreasing elastically with excess labor services. Therefore, we can conclude that it is the firm's current capital stock and labor services which determine the short-run changes in labor services. The short-run effects of output and prices are negligible.

Table 7.19. Short-Run Elasticities for Changes in Labor Services. [a]

With respect to	Full Sample Model	Deregulated Subsample Model	Deregulated Subsample Model Corrected for Heteroskedasticity
Output	-0.00422	-0.0108	-0.00727
Prices:			
real estate	-0.00236	-0.0299	0.000478
machinery	0.00480	0.0504	0.0191
wage rate	-0.00150	-0.0137	-0.0103
Capital:			
real estate	-0.0711	-0.178	-0.182
machinery	0.0275	-0.0181	-0.0172
Labor	-1.04	-1.31	-1.35

[a] Computed at the parameter estimates in the regime of negative changes in labor services. Elasticities are evaluated at sample means.

7.7 Long-Run Elasticities

Long-run price and output elasticities of capital stocks and labor services are computed by setting optimal net investment $\dot{K}$ to zero, and then solving the resulting equation for K as a function of exogenous prices and output. When the optimal net investment has been set to zero, the resulting capital stock equals the steady state capital stock by definition. We denote the steady state capital stock by $\bar{K}$ and define it by:

$$\bar{K} = (M - rU)^{-1}\Big[Diag\big\{q_i^{-1}\big\}M\big(ra_3 + rH'lnY + rDlnQ\big)\Big]$$

Even though the LeChatelier principle no longer holds in a dynamic model, the elasticity estimates suggest that capital is more elastic with respect to output in the long run than in the short run (Table 7.20). But still the capital stock increases very inelastically with the output level, suggesting scale economies in capital utilization as above. Labor services are decreasing with output, but inelastically. In other words, increasing output will result in labor savings or it does not affect the use of labor.

The long-run price elasticities seem to be very sensitive to the model specification. Even the signs vary between the different models and, therefore, we focus on the deregulated sample models only and, in particular, on the heteroskedasticity corrected model, which is expected to be more robust than the other models.

Real estate capital is suggested to be decreasing with respect to its own price or have no response in the long run . But real estate capital is decreasing with machinery prices and increasing with the wage rate. In other words, real estate and machinery are long-run complements, as expected, but somewhat unexpectedly, real estate and labor are long-run substitutes.

Machinery capital is decreasing in its own price, as expected. It is also decreasing in the price of real estate but increasing in the wage rate. These cross price effects suggest that machinery is a long-run complement for real estate but a substitute for labor, as expected.

Labor services are increasing in the prices of both capital goods and decreasing in the wage rate. The result implies, again, that labor and capital are long-run substitutes. Therefore, we conclude that the estimated long-run price effects support our expectations.

Following Fernandez-Cornejo et al. (1992), the elasticity of scale is defined as: $\frac{\partial J/J}{\partial y/y} = \frac{\partial J/J}{\partial lny}$. It measures how many percentage units the discounted present value of the cost stream is expected to change if the level of output is changed by one percentage unit, ceteris paribus. The estimated elasticity of scale was 0.85 in the heteroskedasticity corrected deregulated model, suggesting economies of scale. In other words, the discounted present value of the cost stream is expected to increase by 8.5 percentage points if the output level is increased by 10 percentage points. This result is consistent with the low output elasticities reported above. We conclude that there is potential for reducing the production cost per unit, and for increasing the competitiveness of the Finnish hog industry, through expanding firm size. If the estimated scale effect holds more than just at the margin, a ten percent reduction in the production costs per unit, for example, would be gained by tripling the size of current production units, ceteris paribus.[11]

Table 7.20. Long-Run Elasticities of Capital Stocks and Labor Services. [a]

Good	Elasticity with respect to	Model Specification		
		Full Sample	Deregulated Subsample	Deregulated Subsample, Corrected for Heteroskedasticity
Real Estate	Output	0.0556	0.00865	0.00323
	Price of			
	real estate	-9.96	-0.116	0.000470
	machinery	0.166	-0.0775	-0.0872
	labor	-0.834	-0.0316	0.117
Machinery	Output	0.00484	0.0525	0.00372
	Price of			
	real estate	0.0390	0.421	-0.162
	machinery	8.60	-1.81	-0.222
	labor	0.106	1.65	0.178
Labor	Output	-0.0248	-0.0443	-0.0118
	Price of			
	real estate	-0.128	-0.849	0.206
	machinery	0.0780	0.543	0.150
	labor	-0.107	-0.910	-0.589

[a] We have first set $\dot{K} = 0$, and then solved the decision rules for optimal steady state capital stock and labor. Elasticities are evaluated at the means.

[11] We have used the term elasticity of scale interchangeably with the term elasticity of size. Nevertheless, the measured scale elasticity does not assume homothetic production technology and, therefore, it allows for optimal substitution effects when output is changed.

7.8 Steady State Capital Stocks and Labor Services

The estimated steady state levels of capital and labor services are well below their observed values in the heteroscedasticity corrected model (Table 7.21). The estimates for steady state labor services are even negative, which cannot be true. Perhaps this inplausible result is caused by a gradual decrease in the observed labor services. Nevertheless, the estimates suggest, as do our findings above, that farms have had excess capital and labor at their exogenously restricted production levels.

Table 7.21. Steady State Capital Stocks and Labor Services.

Good	Full Sample Model	Deregulated Subsample Model	Deregulated Subsample Model Corrected for Heteroskedasticity
Real Estate	1,300	38,900	86,700
Machinery	-3,220	23,300	147,000
Labor	34.1	-49.4	-118

Chapter 8

ECONOMIC IMPLICATIONS FOR THE HOG PRODUCTION SECTOR IN FINLAND

This chapter discusses what kinds of answers our estimation results suggest to the questions given in Chapter 1. The discussion is further, expanded to broader practical implications of the estimation results for the hog production sector in Finland.

In the first section we discuss the prospects the sector has in the light of our estimation results concerning economies of scale. Then we move on to the implications of our results for capital and labor markets. Uncertainty will be discussed in the last section. Throughout the chapter we highlight the connections between our results and the new adjustment programs, which were briefly described in Chapter 2.

8.1 Economies of Scale

Recall from Chapter 1 that one of the most important questions addressed in this study was: is it realistic to expect that the Finnish hog industry can become competitive enough, and reach a cost level, that allows it to survive in the Common Market? Chapter 2 introduced the marked structural differences between the Finnish and Danish hog industries, resulting in production costs that are, depending on the farm group compared, 19-30 % higher in Finland than in Denmark.

The estimated low output elasticities and dynamic scale elasticity indicate that the Finnish hog industry is operating with an increasing returns to scale technology. Increasing output per firm will result in more efficient utilization of farm capital, as well as labor savings. In other words, expanding the farm size will result in labor saving technologies and reduce the labor costs per unit produced. Substantial labor savings are plausible because, in large production units, it is possible to take advantage of technologies such as advanced automatic feeding. Advanced feeding technologies will also decrease feed costs.

The long-run scale elasticity was estimated at 0.85, which suggests that production costs will increase less than the output level when firm size is expanded. If output is doubled the present value of the total production costs will increase by 85 %, which will decrease the average costs per unit produced by 7.5 %. Similarly, if the firm's output is tripled its average production costs will decrease by 10 %[1]. For example, with an initial 400 pig fattening capacity, which is common in Finland, this would result in a fattening capacity of 1,200, a capacity that is still well below the maximum capacity of 3,000 given in Table 2.5. But access to the agri-environmental program requires that a farm has at least 110 hectares of arable land for spreading manure and slurry for 1,200 fattening pigs.

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[1] Note that we are projecting cost reductions outside the range of most of the existing data used in the study and therefore the projections should be interpreted with caution.

Thus, obtaining the 1,200 fattening capacity would imply for most hog farms a substantial land area expansion, too.

Capital costs, including building and equipment, account for 21 % of total production costs on Finnish bookkeeping hog farms. The new investment subsidies will account about 50 % of these capital costs, provided maximum subsidies are granted as reported in Table 2.6. Then, a maximum investment subsidy is estimated to reduce production costs by, roughly, 11 %.

Summing up the long-run scale effects and investment subsidies, it is reasonable to expect that the Finnish hog industry has potential for reaching the average cost level of the Danish hog industry had in 1995. But to reach the Danish cost level of 1995, Finnish production units would have to at least triple their size. This implies that the estimated investment size in the survey of Kallinen et al. (1996), which results in the production units of 1.6 times their current size, seems too small for fully adjusting in a new market environment.[2]

An aggregate production level that meets the domestic demand for pork is a feasible goal for the industry, because the EU-Commission has approved means for paying extensive investment subsidies in Finland as long as the aggregate production does not exceed its level in 1994. In this respect the future of the Finnish hog industry seems favorable. It has to be emphasized, however, that tripling the average firm size, while keeping the aggregate production capacity constant, requires that two thirds of the current

[2] Note also that the Danish hog industry is not stagnated at 1995 structure. Danish production units continue to expand and decrease their costs from the costs in 1995.

producers need to exit the industry. Over a five year period, for example, this would require an exit rate of 8 % per year, which is almost twice the 4.3 % average exit rate of 1996 in Finnish agriculture. Even though it is estimated that 10 % of hog producers quit in 1995, the estimate of Kallinen et al. (1996) that 5 % of farms will exit over the two-year period 1996-97 appears too small for adjusting to the new market environment over the five-year transitional period.

If high cost producers who are not going to stay in the industry in the long-run do not exit the industry quickly enough, the investment program may temporarily increase production in excess of domestic demand. But taking into account the aggregate capacity restrictions imposed by the investment program, it is not reasonable to expect that the industry could significantly penetrate the export market for bulky pork products for a any length of time. In other words, it seems unlikely that the industry could reach such a low cost level that it could compete in the export market without subsidies.

Concerning short-run scale economies, we found the important result that, when allowing for fixed and asymmetric adjustment costs, instantaneous production costs are not increasing in investment as traditionally postulated in the literature dealing with adjustment costs. Our results support the view that adjustment costs exist, but the instantaneous cost function is decreasing in investment and larger investments will result in lower adjustment costs. In other words, there are scale economies in investment.

The result that the cost function is decreasing in investment, combined with long-run economies of scale, has important consequences for the adjustment of the Finnish hog industry in the European Common Market. It suggests that the production technology favors large scale industrialized hog production and fast adjustment to the new market environment. In other words, when the timing for an investment is right, farmers should choose new technology and implement large investments in order to get the highest benefits from the new technology and reach the lowest possible production costs per unit produced.

8.2 Capital and Labor Market

As noted in Chapter 1, the most important issues concerning the capital and labor market addressed in this study are: Do the observed and steady state capital stock and labor differ and, if they do, then by how much; how quickly capital and labor adjust towards their steady states; and how are the markets for capital goods and labor linked?

There is no evidence supporting the view that either credit market rationing, or firms' high liabilities to gross return ratios, have resulted in liquidity constrained investments. The results suggest that the discounted value of the firm's cost stream was increasing in capital within the regulated as well as deregulated farm groups. Hence, hog farms appear to have unconstrained access to capital. Furthermore, the shadow price estimates support the often posed view that Finnish hog farms have had excess capital relative to their production levels, which has resulted in inefficient utilization of farm capital. Therefore, it is likely that the stringent production controls in the 80s and early

90s have resulted in a shortage of profitable investment alternatives for farm families to develop their enterprises.

One explanation for the estimated shadow prices is that opportunity cost for farming capital has been low. This result is also supported by Penttinen et al. (1996), who concluded that returns to forest investments, which are natural opportunities for agricultural investments in Finland, have been low. Alternatively, excess capital may have decreased costs that we have not observed. An example of these kinds of unobserved costs are costs or foregone returns caused by a delayed harvest. Similarly, there may have been a tendency towards excess capital. For example, excess harvesting capacity has been to some extent a risk reducing input so that even though it has not increased expected net returns it has decreased the variance of the returns. Nevertheless, we simplified our analysis by assuming risk neutral farmers and, therefore, could not address this issue formally in this study.

There have also been other institutional incentives and regulations that may have triggered investments in excess capital. For example, the imposed link between the farm's arable land area and the maximum size of the livestock unit may have resulted in excess real estate capital relative to the firm's output level. This regulation has been, of course, environmentally justified, but it may also have implied increased costs in livestock husbandry so that marginal returns to livestock have been capitalized into land values. This phenomenon is supported by Ylätalo's (1991) result that land prices have exceeded the marginal value product of land.

The estimated shadow price for machinery is more positive than the shadow price for real estate, which suggests that farmers have had, in addition to individual tastes, even more incentives to invest in machinery than in real estate. This incentive may have been caused by risk reducing characteristics of machinery capacity or by tax shields, generated by high marginal income tax rates and the difference between the tax and economic depreciation rates. Because the tax depreciation rate has exceeded the economic depreciation rate then firms have been able to postpone their tax outlays, while guaranteeing adequate equipment for future production.

Nevertheless, we conclude that, when Finland entered the EU, most hog farms had a reserve, or savings, in terms of excess farming capital which can be utilized for expanding the firm's production. As production controls have been abolished, farm capital will be more efficiently utilized and allocated. But still, low returns to farm capital cause severe difficulties in the farmers' adjustment to a new market environment. Access to credit, on the other hand, is not a problem. Rather, investments accepted in the programs, or recommended to be carried out, should be more carefully considered by institutions which participate and intervene in the agricultural investment programs. The results support the view that farm investments have been carried out with low returns to capital.

The estimated positive elasticities of investments with respect to their own capital stock, on the other hand, suggest that low existing capital stock is required for triggering new investments. Therefore, farmers may need to depreciate the old technology first, especially if it is inflexible in its design, to obtain the most profitable timing for new investments. The result implies that farmers who have invested quite recently, say in late 80s or early 90s, in inflexible production facilities may have difficulties in adjusting quickly to the new market environment.

The adjustment rates for capital are estimated at low values, which also suggests that capital stock and labor will adjust slowly towards their steady state values. The adjustment rate of real estate capital with respect to discrepancy between its current and steady states was estimated at -0.07. This indicates that over a five-year period, after a shock changing the steady state level has been observed, the discrepancy between the actual and the steady state capital stock will shrink by 30 %, i.e. by less than one third. In this light, the five-year transitional period would not be long enough for adjusting to the new market conditions.

It is likely that the low adjustment rate of real estate capital is influenced by market failure in the local land market such that farmers have not had adequate access to land. When supplementary land has been available they have bought it even though the price has exceeded marginal value product of land. The supply of land has been further decreased, for example, by the old early retirement contracts, which included an incentive for retiring farmers to idle their land. As mentioned above, the land market failure is also supported by Ylätalo's (1991) result that strong demand for supplementary land and low supply for land has increased land values even above their marginal value products.

It is expected that the low estimated adjustment rates for machinery, on the other hand, have resulted primarily from unobserved individual effects, which we have not been able to control for. These individual effects may have been caused by tax shields, as explained above, or individual tastes. That is, some farmers have preferred new to old equipment.

We conclude that, even though farms have had excess capital, land market failure will slow down the adjustment process, because the maximum size of a hog production unit is tied to the farm's arable land area, which is justified by environmental arguments. Therefore, it is expected that environmental regulations, which tie the size of the firm's hog production unit and land area together, are going to play an increasingly important role in determining hog production costs, hog industry structure, and the hog industry's spatial concentration.

Labor services are estimated to be decreasing with an adjustment rate estimated at -0.13, implying that the discrepancy between the current and steady state labor is reduced by 50 % over a five-year period. The low adjustment rate, combined with the result that farms have excess labor, signals that farmers have not been able to find enough employment alternatives, while the demand for farm labor has been gradually decreasing.

Labor adjusts asymmetrically in the sense that increasing labor services are even more sluggish than decreasing labor services. The result supports the view that, when more labor is needed in the short run, it is not available or, alternatively, the labor market is inflexible with regard to short-term hiring contracts. In other words, the results suggest that there is market failure in the rural labor market, which will slow down the industry's adjustment process.

Labor and capital markets are closely linked. An inflexible labor market, combined with excess labor in farming, will delay the substitution of capital for labor. Another important finding is that the demand for labor is more likely decreasing than increasing in the firm's output level. Therefore, structural adjustment programs stimulating investments and focusing on the capital market will result in increased excess labor not only among the contracting (or exiting) firms but also among the expanding firms. In other words, an adjustment program stimulating investments will accelerate the decrease in the demand for farm labor in the hog industry. These results also question the rationale of "the full-time farming" -condition as a prerequisite for a farmer to be eligible for the investment programs. It is likely that the requirement for full-time farming will result in inefficient labor allocations and decreased returns to labor on hog farms.

It is not sustainable in the long run to enhance current farm employment in the hog sector. This will only result in inefficient labor allocations, raise labor costs, and decrease farmers' labor income. Decreasing labor costs are crucial in improving the competitiveness of the hog industry through expanding size. The fast decrease of the number of active farmers will, nevertheless, have a real cost for rural areas and society as a whole through the multiplier effects caused by decreasing employment and purchasing expenditure.

We conclude that, even though production technology favors large scale industrialized production units and large one-time investments, it is likely that the industry's adjustment to the new market environment will be retarded by market failures in the local land and labor markets. It is crucial, therefore, that early retirement plans and alternative employment activities increase the supply of land (either leasing or selling) and decrease the number of households supported by the hog industry. In other words, to decrease the hog industry's adjustment costs and to promote the industry towards a competitive structure it is important that adjustment programs focus on decreasing transactions costs in rural labor and land markets. Further, because land constraints may retard farmers from reaching low costs with environmentally friendly practices for spreading slurry and manure, trade in manure between farms should be promoted. Contracts to trade manure could replace expensive and sluggish land trading (either purchases or leases) transactions and, therefore, decrease hog industry's adjustment costs.[3]

8.2 Uncertainty

Our results indicate that uncertainty has a significant effect on investments. The modeled persistent shift in uncertainty decreased investments and slowed down the substitution of capital for labor. This would imply that uncertainty will slow down adjustment significantly, even though investment subsidies provide challenging incentives for investments by reducing the capital costs as much as 50 %.

Nevertheless, the combined effects of the adjustment programs produce not only an exceptional incentive to invest but also a disincentive to postpone investment. The gradually decreasing direct income payments per capacity unit, the marked investment

[3] By flexible environmental regulations we do not mean loosened standards of nutrient leakages. Instead, contracts between firms could be designed to decrease their costs, given the standards for nutrient leakages.

subsidies, and the risk that the program will run out of sufficient funding trigger a farmer to invest as soon as possible, if he considers investing and plans to stay in business in the long-run. The expected lost subsidies for delaying investments outweigh the compensations required for the market risks involved in the investments, and it pays to start risky investments as soon as possible. This phenomenon is supported by the observation that investments started to emerge already in 1995 and 1996, even though farmers did not know whether investment subsidies would be granted. In other words, it paid for early investors to take the advantage of high direct income payments over the first years in the EU, as compensation for the market risk and the risk that they may not be eligible for the investment programs afterwards.

It is expected, therefore, that the extensive adjustment programs, combined with the effects of the direct income subsidies, are hastening adjustment of the Finnish hog sector to the new market environment. The final effects of the adjustment program depend on how much funds are used for subsidizing investments in the hog sector.

Chapter 9

SUMMARY AND CONCLUSIONS

The goal of this study was to investigate the effects of frictions caused by uncertainty, irreversibility, and adjustment costs on investments in Finnish hog farms. External restrictions, such as liquidity constraints caused by credit rationing, were also studied. The main goal was to obtain estimates for adjustment rates, elasticities, and shadow prices while allowing for corner solutions in the farmers' investment choices. The most important questions addressed were: does the production technology exhibit long-run scale economies; do adjustment costs exist and, if they exist, how are they best characterized; how are capital and labor markets characterized; how do investments respond to shocks in input prices and the output level; and how does uncertainty affect investments?

The study develops a method for estimating a generalized model of investment which is consistent with the dynamic theory of the firm. The model accounts for price and output uncertainty, irreversibility, and generalized adjustment costs. Price and output uncertainty are modeled through stochastic transition equations. Adjustment costs are allowed to be asymmetric in investment, to have nonzero intercepts (fixed adjustment costs), and to have kinks at zero investment. Thus, the study makes a contribution to the current investment literature by estimating a generalized investment model so that irreversible investment behavior is allowed to arise either from generalized adjustment costs or from uncertainty, or both.

The model is estimated for a group of Finnish hog farms over the period 1977-93. The model has two endogenous quasi-fixed capital goods, real estate and machinery. Gross investments in real estate and machinery are each allowed to have positive values or, alternatively, be trapped at zero. The third endogenous quasi-fixed input is labor services which is either negative or positive, but is not zero. The fourth endogenous variable is an aggregated variable input that is used as a numéraire. Consequently, a system of four decision rules is estimated. Two out of the four decision variables are allowed to be zero with positive probability. The sample is endogenously partitioned into the regimes of zero and positive investments (four regimes in total) and, then, the decision rules are jointly estimated using the maximum likelihood technique outlined in Chapter 5. The estimated model has a similar structure to the censored Tobit model.

The results suggest that the Finnish hog industry is operating with increasing returns to scale technology. Increasing firm size will result in labor savings and more efficient utilization of farm capital. Summing up the long-run scale effects and investment subsidies, it is reasonable to expect that the Finnish hog industry has potential for reaching the average cost level the Danish hog industry had in 1995. But to reach the Danish cost level, Finnish production units have to at least triple their size.

There are also short-run scale economies in investments so that the larger the investment is the lower adjustment costs realized. This result, combined with long-run economies of scale, has important consequences for the adjustment of the Finnish hog industry in the European Common Market. It suggests that the production technology favors large scale industrialized hog production and drastic one time expansions. In other words, hog production technology favors fast adjustment, or a swift to the new market environment.

The results support the often posed view that the stringent production controls have resulted in shortage of farm investment alternatives and inefficiently utilized, excess capital on Finnish hog farms. This has, furthermore, implied low returns to farming capital. But now as the production controls have been abolished, it is expected that farm expansion provide a potential for more efficiently utilized and allocated farm capital. The initial excess farm capital as well as farmer easy access to credit can allow for access to large investments and fast adjustment.

But even though production technology favors fast adjustment to the new market environment and farmers appear to have unconstrained access to credit, it is likely that the adjustment will be slowed down by inflexibilities and market failures in the local labor and land markets. The adjustment rates for capital and labor were estimated at low values, which suggests that capital stock and labor will adjust slowly towards their steady states. Labor and capital markets are also closely linked to each other so that an inflexible labor market, combined with excess labor in farming, will delay substitution of capital for labor.

Concerning the labor market, tripling the firm size would require an exit rate of almost twice as large as the realized, actual average exit rates, provided expansions are carried out over the five year transition period and aggregate production is kept constant. In other words, the results signal that realized exit rates seem too small and rural labor market does not allow for adjusting fast enough to the new market environment. For hastening the adjustment it is, therefore, important that early retirement plans and alternative employment programs increase the supply of land and decrease the number of households employed in the hog industry.

The substantial structural shift needed to enhance a competitive industry structure is going to have a real cost, because two thirds of the current producers would need to exit the industry. These costs will be realized in terms of adjustment costs to the exiting farmers and multiplier effects on local economies. Even though new investments on capital goods and facilities generate positive multiplier effects in the local economy there are negative multiplier effects too. These negative effects are caused by falling population and income in rural areas which further reduce local consumption expenditures and shrink local businesses.

Our results suggest that environmental regulations are going to play an increasingly important role in determining hog production costs and spatial concentration of the hog industry. The reasons for this are the combined effects of size economies in the industry and environmental regulations, which tie the maximum size of the firm's hog production unit and land area together. These environmental regulations are justified, of course, because they aim at environmentally friendly utilization of manure and slurry. But if there are market failures in the local land market, as our results suggest, inflexible regulations may substantially increase hog production costs and slow down industry adjustment. Therefore, it would be essential to promote not only land trading and leasing transactions but also transactions to trade manure and slurry. The hog industry's adjustment costs could be decreased if, for example, hog farms' land area requirements could be at least partially reduced through contracts of trading manure from hog farms to organically cultivated farms.

Our results indicate that uncertainty has a significant effect on investments. The modeled persistent shift in uncertainty decreased investments and substitution of capital for labor. This implies that uncertainty will slow down the adjustment significantly even though investment subsidies provide challenging incentives for investments by reducing capital costs as much as 50 %. Nevertheless, the combined effects of the adjustment programs produce not only an exceptional incentive to invest but also a disincentive to postpone investment. It is therefore expected that the programs will considerably hasten hog sector's adjustment to the new market environment.

A need for further investment analysis is evident. Some of our estimation results may suggest significant farm specific individual effects, which are unobserved and which we have not been able to control for. Therefore, unobserved individual effects on investments or, more importantly, investment analysis in which time constant individual effects have been factored out, require more research than we have been able to conduct in this study. New methods have already been developed for factoring out unobserved individual effects in discrete choice models and in dynamic models estimating Euler equations (see Wooldridge 1995). These new methods open new alternatives for conducting empirical research on investment behavior.

For conducting accurate investment analysis and implementing correct investment decisions it would be essential to get further insights on how volatile the agricultural commodity markets are in Finland and how well they are integrated to the markets in other

European countries. The effects of agricultural adjustment programs on farmer welfare hinges crucially on how well the supply shocks caused by these programs are absorbed in the markets. This, in turn, depends on how well the Finnish commodity markets are integrated to the commodity markets in other European countries. Further research is also called for to develop methods for insuring against risks involved in drastic agricultural investments.

This research has focused on expanding farms, but it has suggested that it is the low exit rate that will slow down the hog sector's adjustment to the new market environment. For better understanding the combined effects of the retirement plans, alternative employment programs, and investment programs it would be essential to study further the characteristics of the discrete decision between the three alternatives: exit, continue with current size, or expand. New knowledge of decisions between these discrete choices would be valuable help for designing optimal adjustment programs that increase farmer and society welfare.

As explained above, it is expected that hog industry adjustment, the resulting industry structure, and the industry's spatial concentration within and among the European countries, will depend on environmental regulations. Therefore, it would be essential to study in detail how these regulations might be designed for promoting an environmentally friendly, competitive, and spatially balanced hog industry structure in Europe.

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APPENDICES

APPENDIX A

Parameter Estimates with the Data Split into the Credit Market Regimes

The Model Estimated over the Period of Rationed Credit Market 1977-85.

Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
a_{x0}[b]	1.0397	0.0395	H_1	0.2016	0.3526
			H_2	0.2759	0.2925
a_{11}	-0.0318	0.0206	H_3	-0.6730	0.3581
a_{12}	-0.7054	0.1257			
a_{13}	0.0504	0.0258	D_{11}	-0.2503	0.000
			D_{21}	0.2100	0.000
a_2	1.0741	0.3527	D_{22}	-1.9823	0.000
			D_{31}	-0.3564	0.000
a_{31}	-0.2172	0.000	D_{32}	0.6326	0.000
a_{32}	-0.8714	0.0795	D_{33}	-1.3302	0.000
a_{33}	-1.0683	0.000			
			M_{11}	0.1001	0.0105
A_{11}	-0.0031	0.0015	M_{21}	-0.0059	0.0053
A_{21}	0.0096	0.0049	M_{22}	0.0210	0.0319
A_{22}	0.0840	0.0588	M_{31}	0.0046	0.0079
A_{31}	-0.0021	0.0011	M_{32}	-0.0139	0.0077
A_{32}	-0.0051	0.0058	M_{33}	0.1507	0.0091
A_{33}	-0.0040	0.0021			
			γ *for* $\dot{L}>0$	0.2095	0.0078
E_1	-0.0216	0.0163			
E_2	-0.3799	0.5146	$-\sigma^2_{q1}$	.	.
E_3	0.0348	0.0202	$-\sigma^2_{q2}$	.	.
B	0.9123	0.0805	$-\sigma^2_{q3}$	.	.
			bad year	0.0037	0.0261

[a] The number of observations is 845 and the average value of the loglikelihood function is 1.308.
[b] An intercept in the demand equation for the numéraire input. It is a function of structural form parameters.

APPENDIX A

The Model Estimated over the Period of Nonrationed Credit Market 1986-93.

Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
a_{x0}[a]	1.0387	0.0651	H_1	0.2017	0.3108
			H_2	0.2760	0.7617
a_{11}	-0.0322	0.0174	H_3	-0.6730	0.2571
a_{12}	-0.7054	0.1005			
a_{13}	0.0501	0.0322	D_{11}	-0.2502	4.1529
			D_{21}	0.2103	0.000
a_2	1.0740	0.3705	D_{22}	-1.9822	0.000
			D_{31}	-0.3559	2.0032
a_{31}	-0.2173	1.9646	D_{32}	0.6331	0.000
a_{32}	-0.8715	0.000	D_{33}	-1.3302	0.000
a_{33}	-1.0684	0.000			
			M_{11}	0.1010	0.0079
A_{11}	-0.0003	0.0009	M_{21}	-0.0004	0.0029
A_{21}	0.0091	0.0024	M_{22}	0.0226	0.000
A_{22}	0.0840	0.0182	M_{31}	0.0082	0.0060
A_{31}	-0.0002	0.0010	M_{32}	-0.0068	0.0047
A_{32}	-0.0030	0.0049	M_{33}	0.1530	0.0089
A_{33}	-0.0019	0.0023			
			γ *for* $\dot{L}>0$	0.2085	0.0078
E_1	-0.0221	0.0107	$-\sigma^2_{q1}$	- 0.0257	0.0093
E_2	-0.3799	0.0878			
E_3	0.0348	0.0204	$-\sigma^2_{q2}$	- 0.1603	0.0114
			$-\sigma^2_{q3}$	- 0.0180	0.0084
B	0.9122	0.0735	bad year	0.0035	0.000

[a] The number of observations is 1,083 and the average value of the loglikelihood function is 1.109.
[b] An intercept in the demand equation for the numéraire input. It is a function of structural form parameters.

APPENDIX B

APPENDIX B

Response Probabilities and Short Run Elasticities

The Full Sample Model:

Response Probabilities for Positive Investments.

With respect to	Real estate		Machinery	
	gross investment	net investment	gross investment	net investment
Log of output	0.00027	0.00025	0.000174	0.00022
Log of prices:				
real estate	0.00013	0.00012	0.000124	0.00015
machinery	0.00054	0.00052	-0.00060	-0.00074
wage rate	-0.00083	-0.00080	0.00040	0.00049
Capital				
real estate	-0.1346	-0.19206	0.00757	0.00944
machinery	0.00242	0.00233	0.13967	0.02865
Labor	-0.02681	-0.02578	0.03246	0.04045

Short-Run Elasticities of Real Estate Investments.

With respect to	Gross investment		Net investment	
	conditional	unconditional	conditional	unconditional
Output	0.00019	0.000889	0.00019	0.000939
Prices:				
real estate	9.25171	0.000434	9.07699	0.000458
machinery	0.00039	0.001810	0.000379	0.001911
wage rate	-0.00060	-0.00279	-0.000584	-0.00295
Capital:				
real estate	-0.09633	-0.45164	-0.14019	-0.70716
machinery	0.00173	0.00812	0.00170	0.00857
Labor	-0.01918	-0.08994	-0.01882	-0.09493

APPENDIX B

Short-Run Elasticities of Machinery Investments, Evaluated at the Means.

With respect to	Gross investment		Net investment	
	conditional	unconditional	conditional	unconditional
Output	0.000361	0.000592	0.00035	0.00072
Prices:				
real estate	0.000256	0.000420	0.00025	0.00051
machinery	-0.001233	-0.00202	-0.00118	-0.00247
wage rate	0.000822	0.001347	0.00079	0.00164
Capital:				
real estate	0.015687	0.02571	0.01505	0.03139
machinery	0.28936	0.47422	0.04570	0.09530
Labor	0.067244	0.11020	0.06451	0.13454

The Nonrationed Subsample Model:

Response Probabilities for Positive Investments.

With respect to	Real estate		Machinery	
	gross investment	net investment	gross investment	net investment
Log of output	-0.00131	-0.00124	0.00208	0.00236
Log of prices:				
real estate	-0.00168	-0.00157	0.00406	0.00460
machinery	0.01086	0.01021	-0.01390	-0.01574
wage rate	-0.01041	-0.00978	0.00963	0.01091
Capital				
real estate	-0.18617	-0.23275	0.07946	0.08999
machinery	0.02141	0.02013	0.10609	-0.02773
Labor	-0.06318	-0.05940	-0.02385	-0.02700

APPENDIX B

Short-Run Elasticities of Real Estate Investments.

With respect to	Gross investment		Net investment	
	conditional	unconditional	conditional	unconditional
Output	-0.00107	-0.00514	-0.00105	-0.00544
Prices:				
real estate	-0.00137	-0.00656	-0.00134	-0.00694
machinery	0.00886	0.04250	0.00867	0.04495
wage rate	-0.00849	-0.04073	-0.00831	-0.04307
Capital:				
real estate	-0.15197	-0.72876	-0.19762	-1.02477
machinery	0.01747	0.08379	0.01709	0.08861
Labor	-0.05158	-0.24733	-0.05044	-0.26155

Short-Run Elasticities of Machinery Investments, Evaluated at the Means.

With respect to	Gross investment		Net investment	
	conditional	unconditional	conditional	unconditional
Output	0.00333	0.00634	0.00318	0.00765
Prices:				
real estate	0.00650	0.01237	0.00621	0.01492
machinery	-0.02225	-0.04231	-0.02123	-0.05105
wage rate	0.01542	0.02932	0.01472	0.03538
Capital:				
real estate	0.12722	0.24194	0.12142	0.29192
machinery	0.16986	0.32301	-0.03742	-0.08995
Labor	-0.03818	-0.07261	-0.03644	-0.08760