



An Optimal Ownership Structure for Cooperatives

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An optimal ownership structure for cooperatives

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U·M·I
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AN OPTIMAL OWNERSHIP STRUCTURE FOR COOPERATIVES

A thesis presented

by

Alexander Philips Willem van Wassenauer

to

the Standing Committee on Business Economics

in partial fulfillment of the requirements

for the degree of

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in the subject of

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Cambridge, Massachusetts

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ABSTRACT

This thesis identifies an optimal ownership structure for cooperatives. The objective of this structure is to maximize the joint income of the members of that cooperative. To achieve this objective, this structure must resolve two problems which are inherent in the cooperative form of ownership: the Coordination Problem and the Horizon Problem.

The Coordination Problem is how the members of a cooperative can coordinate their private decisions to maximize their joint income if they are not alike. The Horizon Problem is how a cooperative's members can capture its future profits which are due to their past investments in the cooperative if they leave the cooperative before these investments have paid off.

In this thesis, I use a cooperative decision model to derive a budget-balanced, implementable profit-sharing rule which resolves these two problems. The cooperative ownership structure which is based on this rule has two properties: the members of the cooperative share its profit in proportion to their share of its patronage and they can sell the right to use the cooperative on a market for patronage rights.

This thesis contains three case studies of cooperatives which show that the Coordination Problem cannot be fully resolved if the cooperative trades several products with its members, if it can compete with its members and if its members can improve the cooperative's profit by their inobservable effort.

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to Sara

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CHAPTER ONE: SUMMARY AND CONCLUSIONS

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1.1 Introduction

This thesis identifies an optimal ownership structure for cooperatives. The objective of this structure is to maximize the joint income of the members of that cooperative. To achieve this objective, this structure must resolve two problems which are inherent in the cooperative form of ownership: the Coordination Problem and the Horizon Problem.

The Coordination Problem is how the members of a cooperative can coordinate their private decisions to maximize their joint income if they are not alike. The Horizon Problem is how a cooperative's members can capture the future profits which are due to their past investments in the cooperative if they leave the cooperative before these investments have paid off.

In this thesis, I use a cooperative decision model to derive a budget-balanced, implementable profit-sharing rule which resolves these two problems. The cooperative ownership structure which is based on this rule has two properties: the members of the cooperative share its profit in proportion to their share of its patronage and they can sell the right to use the cooperative on a market for patronage rights.

This thesis contains three case studies of cooperatives which show that the Coordination Problem cannot be fully resolved under all circumstances.

This chapter summarizes the main conclusions of this thesis. Section 2 defines a cooperative and it describes why it is formed. Section 3 describes the Coordination Problem and it explains under what circumstances profit-sharing in proportion to patronage resolves this problem. Section 4 describes the Horizon Problem and it explains under what circumstances an ownership structure with patronage rights resolves it.

The remainder of this thesis is organized as follows. Chapter 2 first describes the Coordination Problem in detail. It then introduces a model which describes the decision making process by the members of a cooperative in a single-period economy. This model is used to prove that profit-sharing in proportion to patronage resolves the Coordination Problem. The chapter concludes by discussing under which circumstances this method of profit-sharing does not ensure that a cooperative's members make decisions which maximize their joint income.

Chapter 3 first describes the Horizon Problem. It then describes how patronage rights resolve this problem and it mentions some of its other benefits. Then, a two-period variation of the cooperative decision model is used to prove that this ownership structure resolves the Horizon Problem, while an ownership structure with revolving equity does not.

Chapters 4, 5 and 6 are case studies of agricultural cooperatives. These cases show that the Coordination Problem discussed in chapter 2 cannot be fully resolved in all circumstances. The subject of these cases is briefly described below and they are referred to in chapters 2.8 and 3.4.2.

Chapter 4 describes the merger negotiations between three major U.S. cooperatives: Farmland, Cenex and Land O'Lakes. These negotiations broke down in 1989, in part because the three cooperatives could not agree how to strike a balance between enabling the merged cooperative to exploit the synergies between its various activities and ensuring that the its members would not have to subsidize investments in activities whose profits they did not share.

Chapter 5 describes the Cooperative Company Friesland (CCF), one of the world's largest suppliers of condensed milk. CCF was owned by five dairy cooperatives which produced a range of dairy products themselves. In 1987 and 1988, CCF suffered large losses, partly because it had been barred from competing in more profitable segments of the European dairy market by its members, to prevent it from competing with them. In addition, the allocation of milk between CCF and its members was suboptimal, partly because there was no unambiguous measure of the profitability of CCF relative to that of its members.

Chapter 6 describes the New Zealand Dairy Board, the export marketing organization owned by New Zealand's dairy cooperatives. The Board pursued a global, market-driven strategy with the objective to increase its sales of specialized dairy products. To achieve this objective, the Board wanted to encourage its member cooperatives to acquire the skills which were needed to produce more specialized dairy products, without losing its ability to coordinate their production decisions.

1.2 Definition of a Cooperative

I define a cooperative as a firm which is owned by firms or individuals who supply it or who buy from it. This broad definition of a cooperative includes agricultural, financial and consumer cooperatives as well as labor-managed firms, unions, professional partnerships, clubs, and public projects whose beneficiaries can be identified and taxed for using the project, including most public infrastructure, education and health care. However, my vantage point in this thesis is that of the agricultural marketing cooperative.

A member of a cooperative is an individual or a firm who is one of its owners and who supplies that cooperative or who buys from it. A cooperative's patronage is the total volume of the product supplied to or bought from the cooperative by its members. This can be any product or service supplied by or sold to its members, including their own labor or capital. I assume in this thesis that a cooperative processes some product which is produced by its members. However, the results of this thesis apply to all cooperatives covered by the definition above, as is shown in section 2.6.

A cooperative differs from an investor-owned firm and from a public good. The difference between a cooperative and an investor-owned firm is that the owners of an investor-owned firm do not trade with it, while the members of a cooperative do trade with it. The difference between a

cooperative and a public good is that, in the case of a public good, it is impossible to let each of its beneficiaries, or owners, use a different amount of that good, depending on each owner's private preferences, and to tax each owner according to his use of that good. In contrast, each of the members of a cooperative may supply a different volume of product to it and a member's share of the cooperative's profit may depend on the volume he supplies to it.

A cooperative may be established if its members can jointly earn a higher income if they supply the cooperative and share its profit than if they process their product individually, or if they sell their product to another firm. In this thesis, I assume that economies of scale of a cooperative's activities are such that it is unprofitable for the cooperative's members to engage in these activities individually. The producers of a product may earn a higher income if they establish a cooperative than if they sell their product to another firm if, without a cooperative, there is a lack of competition among the buyers of that product. In that case, the buyers may pay an oligopsonistic price for the product produced by their suppliers and, if producers invest in improving product quality or productivity, the buyers of the product may appropriate the return on these investments by manipulating the price they pay for that product.

A different reason for establishing a cooperative is to enable the producers of a product to monopolize its supply. To achieve this, such a cooperative will attempt to attract all producers of that product as members and it will attempt to coordinate their production decisions. Masson et al [1977] document evidence of the success of this strategy in a regulated market. However, at least one case study suggests that, in the absence of regulatory barriers, this objective cannot be achieved, because the cooperative's members have an incentive to sell their product behind the cooperative's back and because the cooperative does not control the supply of nonmembers. [van Wassenauer, 1988] Therefore, I assume in this thesis that suppliers establish a cooperative because of lack of competition among the buyers of their product, not to monopolize its supply.

1.3 The Coordination Problem and Proportional Profit-Sharing

The Coordination Problem concerns the question how the members of a cooperative can maximize their joint income by coordinating their decisions concerning their individual production and the cooperative's policies. Under the assumptions stated in section 1.2, the income of each member of a cooperative equals his share of its profit minus his cost of production. The cooperative's members may not agree with each other what decisions are optimal if they do not have the same private characteristics and if these are inobservable.

As I prove in chapter 2, a cooperative's members can resolve this problem by sharing its profit in proportion to each member's share of the cooperative's patronage. This profit-sharing rule is adopted by most cooperatives throughout the world. If a cooperative adopts this rule, each member will make efficient private production decisions and all members will unanimously agree on the cooperative's policies, whatever their individual characteristics are, and no matter whether they make their decisions individually or in a coalition.

In this case, the cooperative's optimal size is the size which maximizes its profit per unit of patronage. To reach this size, cooperatives must adopt a closed membership policy. However, a cooperative can accept any type of producer as a member in the cooperative if it adopts this profit-sharing rule, as long as each member supplies the same product.

1.4 The Horizon Problem and Patronage Rights

The Horizon Problem concerns the question how the present members of a cooperative can capture its future profits due to their past investments, if they reduce their share of the cooperative's patronage before these investments have paid off, for example because they leave the cooperative. If the present members of a cooperative plan to reduce their share of the cooperative's patronage and if no mechanism exists which allows them to capture these profits, they will invest less in their cooperative than they would if such a mechanism did exist. This reduces their joint income.

It is explained in chapter 3 that, if a cooperative has an ownership structure with revolving equity, its members share the cost of an investment by the cooperative in a certain asset in proportion to their share of the cooperative's patronage in the period that this cost is incurred and they share the profit generated by this asset in proportion to their share of the cooperative's patronage in the period that this asset pays off. Such an ownership structure may resolve the Horizon Problem for an asset which pays off only in the period when its cost is incurred. However, I show in chapter 3 that such an ownership structure does not resolve the Horizon Problem for an asset which pays off after its cost has been incurred. If the majority of the members of a cooperative with revolving equity reduces their share of its patronage, it will

underinvest in such an asset. One such asset is an intangible asset, which is expensed in the year that it is acquired. Intangible assets include product and market development.

A cooperative can resolve this Horizon Problem by establishing a market for the right to supply the cooperative. This market would function in much the same way as the stock market for investor-owned firms. On this market, a producer who wants to reduce his supply to the cooperative can sell his patronage rights to another producer who wants to expand his supply. The members can jointly expand or reduce the total size of their cooperative by issuing or buying back patronage rights. I prove in chapter 3 that, if demand for patronage rights is competitive, this market mechanism transfers the cooperative's future profits due to its past investments to its present owners. This resolves the Horizon Problem described above.

There are a number of other advantages to creating a market for patronage rights. The market value of these rights measures the value of supplying the cooperative instead of supplying another firm. This measure can be used to reward outside investors and to structure a cooperative's management incentives as efficiently as an investor-owned firm can. In addition, a cooperative's members can privatize or merge their cooperative by selling their patronage rights collectively to a private investor or by exchanging them for the patronage rights of another cooperative, respectively. Hence, a market

for patronage rights may discipline a cooperative's management in the same way as the stock market disciplines the management of investor-owned firms.

In spite of the apparent advantages of patronage rights, few agricultural cooperatives have adopted them. I argue in chapter 3 that, to be able to compete with private firms in the future, agricultural cooperatives must adopt a more innovative ownership structure. Such a structure should enable a cooperative to attract equity more cheaply from its members and outside investors to invest in intangible assets and it should enable it to reward and discipline its management more efficiently. As is explained above, an ownership structure with patronage rights satisfies these requirements. Therefore, I expect that more agricultural cooperatives will adopt patronage rights in the future.

CHAPTER TWO:
THE COORDINATION PROBLEM AND PROPORTIONAL PROFIT-SHARING

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2.1 Introduction

In this chapter, I prove that an ownership structure in which members share the profits of their cooperative in proportion to their share of its patronage resolves the Coordination Problem. Section 2 describes the Coordination Problem in cooperatives. Section 3 introduces a model which describes the process of decision making of producers who supply a cooperative, if their private characteristics are inobservable. Section 4 defines an optimal profit-sharing rule. This rule resolves the Coordination Problem, is budget-balanced and implementable. Section 5 proves that a profit-sharing rule is optimal if it satisfies two conditions, the Unanimity Condition and the Budget-Balance Condition. Section 6 proves that the only optimal profit-sharing rule is a rule which shares a cooperative's profits in proportion to patronage. Section 7 discusses the implications of this result for cooperatives. Section 8 explains under what circumstances proportional profit-sharing may not fully resolve the Coordination Problem.

2.2 The Coordination Problem

The Coordination Problem concerns the question how the members of a cooperative can maximize their joint income by coordinating their decisions concerning their individual production and the cooperative's policies. It is assumed that this income equals their share of the profit of the cooperative they supply minus the cost of producing the product they supply to the cooperative. The cooperative's members may not agree with each other what decisions are optimal if they do not have the same private characteristics and if these characteristics are not observable or verifiable.

This problem was identified by Jensen and Meckling, who criticized earlier literature on the worker-owned firm as follows: "No one has specified a well-defined set of procedures for solving the decision-making problem within the firm when the preferences of the workers are not all identical. It is simply assumed that workers will have a common set of preferences and that no conflicts will arise in translating these into operational policies at the firm level." [Jensen and Meckling, 1979, p.488] For example, Carson [1977], assumes that the cooperative firm can make its decisions independently of its owners who behave as price takers in their trade with the cooperative, even though they share its profits. Clearly, this approach does not withstand Jensen and Meckling's criticism.

Several authors have attempted to solve the cooperative Coordination Problem, using decision models based on game theory. These include Zusman [1982], Staatz [1983] and Sexton [1986]. These authors address the Coordination Problem by trying to identify a rule for sharing the cooperative's profits in such a way that no member or coalition of members can make himself better off by changing his patronage of the existing cooperative or by forming another cooperative.

Although this may be a satisfactory approach, a fundamental weakness of the models of these authors is that, in these models, the profit-sharing rules which maximize the joint income of the cooperative's members are a function of each member's private characteristics. [Sexton, proposition 1, p.222, Staatz, p.1087, Zusman, p.232] Hence, these rules are useless if these characteristics cannot be observed because, in that case, a member could misstate his characteristics to increase his income, given the profit-sharing rule, even if this reduces the joint income of all producers. In game theory, this is commonly referred to as the revelation problem.

To avoid this problem, an optimal profit-sharing rule must be such that, if each member, or coalition of members, makes decisions concerning his own output and the policies of the cooperative which maximize his income, given his private characteristics and the profit-sharing rule of the

cooperative, the joint income of all members of the cooperative is maximized as well. In addition, these decisions must be implementable and the profit-sharing rule must be budget-balanced. Such a profit-sharing rule is derived in this chapter, using the cooperative decision model described in the next section. This model is similar to the decision model for public goods specified by Laffont and Maskin [1980].

2.3 The Single-Period Cooperative Decision Model

In this section, I first provide an informal description of the single-period cooperative decision model. I then describe this model more formally.

Suppose that there is a very large number of potential producers of a certain product. Each producer's production cost depends on his output and on his production efficiency, or "type", which cannot be verified by an outside observer. It is possible to build cooperatives which can process this product. Each cooperative has a certain capacity which equals the total volume of product supplied to the cooperative by its members, which is the cooperative's patronage. In addition, a cooperative has a number of other characteristics which affect its profitability, including its investments, its debt-structure and the market it competes in. I refer to these other characteristics as the cooperative's "investment".

The net profit of each cooperative equals its net revenues minus the cost of all inputs except the cost of the product supplied to the cooperative by its members, minus the cost of the cooperative's investment. The profit of each cooperative depends on its capacity, its investment and on some exogenous factors, including the prevailing conditions on the markets the cooperative can compete in and the technology of processing the product of its members. I assume that all producers can earn a higher income if they supply a

cooperative than if they supply some other firm, which they do not control. Hence, I ignore the existence of these other firms in this model.

Suppose that there is a game coordinator whose objective is to maximize the joint income of all producers who supply a cooperative. To achieve this objective, the coordinator designs a game which allows each producer to submit a bid stating his own output as well as the capacity and the investment of the cooperative he wants to supply. A producer can choose his bid individually or in a coalition with other producers.

The assumption that each producer can choose the capacity of the cooperative he wants to supply is equivalent to assuming that the cooperative has a closed membership policy and that it admits new members until it has reached its optimal size. In section 2.7, I examine how this model changes if a cooperative has an open membership policy instead.

When all producers have submitted their bids, the coordinator implements these bids by building enough cooperatives such that each producer can supply his chosen output to a cooperative which has the capacity and the investment of his choice and such that the aggregate capacity of all cooperatives equals the aggregate supply of all producers.

A producer who submits a certain bid must supply the output stated in his bid to a cooperative which has the capacity and the investment stated in his bid. In return, he receives a share of the profit of that cooperative. The size of this share depends on the profit-sharing rule, which is announced by the game coordinator before the producers submit their bids.

Within the context of this game, the Coordination Problem is that the decisions of each coalition of producers may not maximize the joint income of all producers. Moreover, the game coordinator may not be able to implement the bids of all producers. Finally, the profit-sharing rule may not be budget-balanced.

The game coordinator can resolve these problems by announcing a profit-sharing rule which maximizes the joint income of all producers when they submit bids which maximize their individual income, or the income of their coalition, and which is implementable and budget-balanced, no matter what each producer's type is. This game is described more formally below, using notation which is summarized in exhibit 1. This exhibit can be found on page II-18.

Technology and Market Conditions

There is a very large population of producers, Γ . A producer in Γ is denoted by the subscript i . Producer i can produce a

product volume a_i . Producer i has a cost of production C_i , which is twice continuously differentiable and strictly convex in a_i and which depends on his type, θ_i . θ_i is a real number. θ_i cannot be observed by the game coordinator and it may vary among producers. Producer i 's marginal cost of production decreases in θ_i .

A producer can supply one or more cooperatives. A cooperative is denoted by the subscript j . Cooperative j has a capacity A_j , which equals its patronage. A cooperative's capacity may be smaller than the production of a single producer who supplies it. In that case, the producer supplies another cooperative as well.

For simplicity, it is assumed that the capacity of a cooperative is financed entirely with debt. In addition, the cooperative can make an investment in certain assets, which may increase the profit of the cooperative, given its capacity. A part of this investment must be financed with equity. Cooperative j 's equity investment is B_j . I assume that the equity investment in the cooperative must be provided entirely by its suppliers. I assume that the opportunity cost of this equity, r , is the same for all producers. In section 3.6, I discuss how this model changes if outside investors can provide a part of the cooperative's equity.

Cooperative j 's gross profit is P_j . P_j equals its total revenues minus the cost of all inputs, except the cost of A_j , which is supplied to it by its members. A cooperative's net profit equals its gross profit minus the cost of its equity investment, rB_j . P_j is twice continuously differentiable and strictly quasi-concave in A_j and B_j . P_j also depends on some exogenous factor, $\bar{\Phi}_j$, which represents the cooperative's technology and the markets the cooperative competes on. I assume that $\bar{\Phi}_j$ has the same value, $\bar{\Phi}$, for all cooperatives. This assumption means that the members of a cooperative can make all decisions which affect its profit relative to that of other cooperatives. These decisions are represented by the vector (A_j, B_j) .

The Bidding Game

First, each producer submits a bid (a_i, A_i, B_i) to the game coordinator. If a producer submits a bid (a_i, A_i, B_i) , he must supply his total output, a_i , to one or more cooperatives, each of which has capacity A_i and investment B_i . In return, he receives a transfer T_i which depends only on his own bid, (a_i, A_i, B_i) . The function T_i is the profit-sharing rule announced by the game coordinator. Hence, this producer earns an income $V_i(a_i, A_i, B_i; \theta_i)$, which equals:

$$T_i(a_i, A_i, B_i) - C_i(a_i; \theta_i).$$

As this is a single-period model, I assume that each element of this bid must be chosen simultaneously. In addition, I

assume that each producer chooses his bid when he knows with certainty how it will affect his income. Chapter 3.5 shows how this model changes if producers must choose their bids under uncertainty.

The next subsection describes how the game coordinator implements these bids. I assume that the game coordinator is wealthy, so that he can always pay $T_i(a_i, A_i, B_i)$ to a producer, even if he cannot implement his bid. However, as I stated in the introduction of this section, I require that the profit-sharing rule is such that, in equilibrium, the game coordinator can implement the bids of all producers and that the aggregate transfers to all producers equal the aggregate profits of all cooperatives. Hence, the game coordinator does not incur any expense in equilibrium.

In section 2.4, I define what conditions T_i must satisfy to meet these requirements. In the remainder of this subsection, I describe the equilibrium which is used to define these conditions. First, I define an individually optimal bid.

Definition Individually Optimal Bid

A producer's individually optimal bid, $(a_i^*, A_i^*, B_i^*; \theta_i)$, solves:

$$\text{MAX}_{(a_i, A_i, B_i)} V_i .$$

This bid is characterized by the first-order conditions to the above optimization problem:

$$\text{FOC}(a_i) T_i^a - C_i^a = 0$$

$$\text{FOC}(A_i) T_i^A = 0$$

$$\text{FOC}(B_i) T_i^B = 0,$$

where the superscripts a, A and B indicate the derivative of a function with respect to a_i , A_i and B_i , respectively.

The solution to these conditions is unique if the Hessian of V_i is negative definite at $(a_i^*, A_i^*, B_i^*; \theta_i)$. To ensure that this solution is unique, I require that a profit-sharing rule is twice continuously differentiable and that it is quasi-concave in (a_i, A_i, B_i) and strictly quasi-concave in (A_i, B_i) at $(a_i^*, A_i^*, B_i^*; \theta_i)$. I also require that $T_i(0, A_i, B_i)$ equals zero, reflecting the assumption that the coordinator cannot identify producers who do not supply a cooperative. Finally, I require that T_i is such that $a_i^* < \infty$ and $A_i^* < \infty$.

Instead of maximizing their income V_i , producers might maximize their utility of income U_i . In that case, their individually optimal bid solves:

$$\text{MAX}_{(a_i, A_i, B_i)} U_i(V_i; I_i),$$

where I_i is producer i 's income preference. Clearly, the individually optimal bid which maximizes a producer's utility of income U_i , given his income preference I_i , is the same as the bid which maximizes his income V_i .

The set Z is a subset of Γ which contains all producers who submit an individually optimal bid with a positive product volume, which does not equal the capacity of the cooperative of his choice. That is, Z is such that:

$$a_i^* > 0, \quad \forall i \in Z \text{ and}$$

$$a_i^* \neq m_i A_i^*, \quad \forall i \in Z,$$

for any positive integer m_i .

If a producer submits a bid such that $a_i^* > 0$ and $a_i^* = m_i A_i^*$, he can be placed in one or more cooperatives by himself and earn all of their profits. Such a producer has no coordination problem. If a producer submits a bid such that $a_i^* = 0$, he does not produce anything and he does not receive any transfer. The vector of types of all producers in Z is $(\theta_i)_{i \in Z}$ and the vector of the individually optimal bids of all producers in Z is $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$.

The integer z is the number of producers in Z . I assume that z approaches infinity. As is shown in section 2.5, this assumption is necessary to ensure that the individually optimal bids of all producers can be implemented. I emphasize that this assumption does not imply that every cooperative is supplied by an infinite number of producers.

As was explained in the introduction of this section, the profit-sharing rule T_i must be such that the bids of the cooperative's members maximize their joint income, whether

they submit their bids individually or in a coalition. I assume that producers can form a coalition which maximizes the joint income of its members, given their types. Any coalition, $C \subset Z$, can submit a vector of bids $(a_i, A_i, B_i)_{i \in C}$ on which no further restrictions are imposed. I define a coalitionally optimal bid as follows.

Definition Coalitionally Optimal Bid

A coalitionally optimal bid, $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in C}$, solves:

$$\text{MAX}_{(a_i, A_i, B_i)_{i \in C}} \sum_{i \in C} V_i$$

The set D is a set of mutually exclusive coalitions of all producers, which are denoted by C_d . That is, D is such that:

$$i \in C_d \Rightarrow i \in Z, \forall d \in D$$

$$i \in Z \Rightarrow i \in C_d, \text{ some } d \in D$$

$$i \in C_d \Rightarrow i \notin C_e, \forall e \neq d, \forall e \in D, \forall d \in D.$$

The vector of coalitionally optimal bids of all mutually exclusive coalitions in D is: $((a_i^*, A_i^*, B_i^*; \theta_i)_{i \in C})_{d \in D}$. This vector is written as: $(a_i^*, A_i^*, B_i^*; \theta_i, D)_{i \in Z}$, for notational simplicity. Each element of this vector, $(a_i^*, A_i^*, B_i^*; \theta_i, D)$, may depend on the coalition to which producer i belongs.

Given these definitions of an individually optimal bid and a coalitionally optimal bid, I now define a Strong Nash Equilibrium in Dominant Strategies in the context of the single-period cooperative decision model. In such an equilibrium, the vector of individually optimal bids of all

producers in Z maximizes the joint income of any coalition of producers $C \subset Z$, no matter what the bids of the other producers in Z are.

Definition Strong Nash Equilibrium in Dominant Strategies

The vector of individually optimal bids $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$ forms a Strong Nash Equilibrium in Dominant Strategies if and only if $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$ solves:

$$\text{MAX}_{(a_i, A_i, B_i)_{i \in C}} \quad \sum_{i \in C} v_i \quad \forall C \subset Z, \quad \forall (a_j, A_j, B_j; \theta_j)_{j \in C, j \in Z} \cdot$$

The definition given above requires that the vector of individually optimal bids of all producers in Z maximizes the joint income of the members of any coalition $C \subset Z$. This requirement is stronger than the standard definition of a Strong Nash Equilibrium, which requires only that the vector of bids of all producers in Z is such that, for each coalition in Z , some producers in that coalition cannot increase their individual income by forming another coalition which submits another bid.

Next, I establish in Fact 1 that the individually optimal bids of all producers in Z form a Strong Nash Equilibrium in Dominant Strategies.

Fact 1. The vector of individually optimal bids of all producers in Z , $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$, forms a Strong Nash Equilibrium in Dominant Strategies.

Proof Fact 1.

Each of the individually optimal bids of the producers in Z is characterized by the first-order conditions to a producer's individual optimization problem stated above. Each producer's transfer, T_i , depends only on his own bid, (a_i, A_i, B_i) . Each producer's cost of production, C_i , depends only on his own output and his own type, (a_i, θ_i) . Hence, each producer's individually optimal bid is independent of $(a_j, A_j, B_j; \theta_j)_{j \in I, j \in Z}$. Furthermore, given the restrictions on T_i and C_i , each of these bids is unique.

Similarly, the coalitionally optimal bid of any coalition $C \subset Z$, $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in C}$, is the solution to that coalition's joint optimization problem. Again, given the restrictions on T_i and C_i , these optimal bids are unique and independent of $(a_j, A_j, B_j; \theta_j)_{j \in C, j \in Z}$. Furthermore, because T_i depends only on a producer's own bid, the first-order conditions which characterize these coalitionally optimal bids are the same as the first-order conditions which characterize the individually optimal bid of each producer who is a member of that coalition. End of proof.

Given Fact 1, the vector of coalitionally optimal bids of all mutually exclusive coalitions in the set D equal the vector of individually optimal bids of all producers in Z . For that reason, I refer only to the vector of individually optimal

bids in defining an optimal profit-sharing rule T_i in the next section, not to the vector of coalitionally optimal bids.

Bid Implementation

When all producers have submitted their individually optimal bids, the coordinator tries to build a number of cooperatives to implement these bids, as follows. The set Z can be divided in subsets Z_S of producers who want to supply a cooperative with the same capacity and investment, (A_S^*, B_S^*) . That is, Z_S is a subset of Z such that:

$$(A_i^*, B_i^*) = (A_S^*, B_S^*), \forall i \in Z_S$$

$$(A_i^*, B_i^*) \neq (A_S^*, B_S^*), \forall i \notin Z_S.$$

Next, the coordinator determines whether there exists a set M of cooperatives which is characterized by a vector of capacities and investments $(A_j^*, B_j^*)_{j \in M}$, to implement the bids of all subsets $Z_S \subset Z$. This set M consists of subsets M_S of cooperatives with the same capacity and investment, (A_S^*, B_S^*) .

That is, M_S is a subset of M such that:

$$(A_j^*, B_j^*) = (A_S^*, B_S^*), \forall j \in M_S$$

$$(A_j^*, B_j^*) \neq (A_S^*, B_S^*), \forall j \notin M_S.$$

I assume that it is very expensive to underutilize a cooperative's capacity. Hence, given the requirement that a profit-sharing rule must be budget-balanced (see section 2.4), the game coordinator can only maximize the joint income of all producers who supply a cooperative by ensuring that the aggregate capacity of all cooperatives in a subset M_S is just

sufficient to process the individual output of all producers in the subset Z_s , who want to supply those cooperatives.

Given these definitions of Z_s and M_s , I now define what conditions the vector $(A_j^*, B_j^*)_{j \in M}$ must satisfy to implement the vector of individually optimal bids $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$.

Definition Implementability for the Single-Period Model

The vector of capacities and investments $(A_j^*, B_j^*)_{j \in M}$ implements the vector of individually optimal bids $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$ if and only if, for each subset $Z_s \subset Z$, there is a subset $M_s \subset M$, such that:

1. $(A_i^*, B_i^*) = (A_j^*, B_j^*)$, $\forall i \in Z_s, \forall j \in M_s$
2. $\sum_{i \in Z_s} a_i^* = \sum_{j \in M_s} A_j^*$.

I use this definition in the next section to state what conditions the profit-sharing rule T_i must satisfy to ensure that the coordinator can implement the individually optimal bids of all producers in Z .

Exhibit 1. Notation for the Cooperative Decision Model

<u>Symbols:</u>	<u>Domain:</u>	<u>Meaning:</u>
a_i	R_+	producer i 's production
θ_i	R	i 's production efficiency, or type.
Z		set of producers which submit bids $(a_i^*, A_i^*, B_i^*; \theta_i)$ s.t. $a_i^* > 0, \forall i \in Z$ $a_i^* \neq m_i A_i^*, \forall i \in Z, \text{ any integer } m_i.$
z	Z_+	number of producers in Z
$Z_S \subset Z$		subset of producers in Z , s.t. $(A_i^*, B_i^*) = (A_S^*, B_S^*), \forall i \in Z_S$ $(A_i^*, B_i^*) \neq (A_S^*, B_S^*), \forall i \notin Z_S$
$C \subset Z$		coalition of producers in N whose optimal bids maximize the joint income of its members.
D		A set of mutually exclusive coalitions $(C_d)_{d \in D}$ s.t. $i \in C_d \Rightarrow i \in Z, \forall d \in D$ $i \in Z \Rightarrow i \in C_d, \text{ some } d \in D$ $i \in C_d \Rightarrow i \notin C_e, \forall e \neq d, \forall d \in D, \forall e \in D.$
A_j	R_+	cooperative j 's capacity, or patronage
B_j	R_+	cooperative j 's equity investment
Φ_j	R	exogenous factor affecting the profitability of cooperatives, s.t. $\Phi_j = \Phi, \forall j \in M.$
r	R_+	opportunity cost of equity
M		set of all cooperatives
$M_S \subset M$		subset of all cooperatives s.t. $(A_j^*, B_j^*) = (A_S^*, B_S^*), \forall j \in M_S$ $(A_j^*, B_j^*) \neq (A_S^*, B_S^*), \forall j \notin M_S.$

<u>Functions:</u>	<u>Meaning:</u>
$C_i(a_i, \theta_i)$	Production costs of producer i
$P_j(A_j, B_j; \Phi)$	Profit of cooperative j
$T_i(a_i, A_i, B_i)$	Transfer to producer i
$V_i(a_i, A_i, B_i; \theta_i)$	Total income of producer i: $V_i = T_i - C_i$

Restrictions on Functions:

$$C_i(0; \theta_i) = 0 ;$$

$$C_i^a(0; \theta_i) < P_j^A(0, B_j; \Phi), \forall \theta_i, \forall B_j ;$$

For $\forall \theta_i, \forall A_j, \forall B_j$, there exists some $\bar{a}_i < \infty$, such that:

$$C_i^a(a_i; \theta_i) > P_j^A(A_j, B_j; \Phi), \text{ for } \forall a_i \geq \bar{a}_i ;$$

$$C_i^{aa} > 0, \forall a_i, \forall \theta_i ; C_i^{a\theta} < 0, \forall a_i, \forall \theta_i ;$$

$$P_j(0, B_j; \Phi) = 0, \forall B_j ;$$

$$P_j^A(0, B_j; \Phi) > 0 \forall B_j ; P_j^B(A, 0; \Phi) > r, \forall A_j ;$$

For $\forall B_j$, there exists some $\bar{A}_j < \infty$, such that:

$$P_j^A(A_j, B_j; \Phi) < 0, \forall A_j \geq \bar{A}_j, ;$$

$$P_j^{AA} < 0, \forall (A_j, B_j) ; P_j^{BB} < 0, \forall (A_j, B_j) ;$$

$$P_j^{AA} P_j^{BB} - P_j^{AB} P_j^{BA} > 0 \forall (A_j, B_j) ;$$

$$T_i(0, A_i, B_i) = 0, \forall (A_i, B_i) ;$$

And, for $\forall (\theta_i)_{i \in Z}$ at $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z} :$

$$T_i^{aa} \leq 0 ; T_i^{AA} < 0 ; T_i^{BB} < 0 ;$$

$$T_i^{AA} T_i^{BB} - T_i^{AB} T_i^{BA} > 0 ; T_i^{aa} T_i^{AA} - T_i^{aA} T_i^{Aa} \geq 0 ;$$

$$T_i^{aa} (T_i^{AA} T_i^{BB} - T_i^{AB} T_i^{BA}) - T_i^{Aa} (T_i^{Aa} T_i^{BB} - T_i^{AB} T_i^{Ba})$$

$$+ T_i^{aB} (T_i^{Aa} T_i^{BA} - T_i^{AA} T_i^{Ba}) \leq 0 .$$

2.4 Definition of an Optimal Profit-Sharing Rule

In this section, I define an optimal profit-sharing rule $T_i(a_i, A_i, B_i)$, as follows:

Definition of an Optimal Profit-Sharing Rule

A profit-sharing rule $T_i(a_i, A_i, B_i)$ is optimal in the single-period model if and only if:

1. T_i satisfies the Implementability Condition.
2. T_i satisfies the Budget-Balance Condition.
3. T_i satisfies the Optimality Condition.

These three conditions are defined below. The Implementability Condition ensures that the individually optimal bids of all producers can be implemented. The Budget-Balance Condition ensures that the aggregate transfers paid to all producers given these individually optimal bids equal the aggregate profits of the set of cooperatives which implement these bids. The Optimality Condition ensures that these bids maximize the joint income of all producers who supply a cooperative. Fact 1 establishes that all producers who supply a cooperative will submit their individually optimal bids, no matter what other producers' bids are and no matter whether they submit these bids individually or in a coalition. Hence, a profit-sharing rule which satisfies the above definition meets the requirements on such a rule stated in the introduction of section 2.3.

First, I define the Implementability Condition. This definition ensures that the coordinator can implement the vector of individually optimal bids of all producers in Z , no matter what their types are.

Definition of the Implementability Condition

A profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Implementability Condition for the single-period model if and only if, for $\forall (\theta_i)_{i \in Z}$, there exists a vector $(A_j^*, B_j^*)_{j \in M}$, which implements $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$.

In the proof of Proposition 1 in section 2.5, I establish that this condition is equivalent to the so-called Unanimity Condition, which is defined as follows.

Definition of the Unanimity Condition

A profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Unanimity Condition if and only if, for $\forall (\theta_i)_{i \in Z}$, $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$ satisfies:

1. $A_i^* = A^*$, $\forall i \in Z$
2. $B_i^* = B^*$, $\forall i \in Z$.

A profit-sharing rule satisfies the Unanimity Condition if all producers who want to supply a cooperative unanimously choose the same capacity and investment, if each producer submits his individually optimal bid. A producer can easily check whether this condition is satisfied for a particular profit-sharing rule, by computing $(a_i^*, A_i^*, B_i^*; \theta_i)$, for all θ_i .

Next, I define the Budget-Balance condition. This condition ensures that the profit-sharing rule is such that the transfers to all producers always equal the profits of all cooperatives, if all producers submit their individually optimal bids.

Definition of the Budget-Balance Condition

An implementable profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Budget-Balance Condition for the single-period model if and only if, for $\forall (\theta_i)_{i \in Z}$,

$$\sum_{i \in Z} T_i(a_i, A_i, B_i) = \sum_{j \in M} [P_j(A_j, B_j) - B_j], \text{ at } (a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$$

and at $(A_j^*, B_j^*)_{j \in M}$ which implements $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$.

This definition of budget-balance is weak in the sense that it only requires that the aggregate net profits of all cooperatives equal the aggregate transfers to all producers who supply a cooperative, not that the net profit of each cooperative equals the transfers to all suppliers of that cooperative. Hence, the Budget-Balance Condition stated above does not exclude the possibility of cross-subsidization among suppliers of different cooperatives. However, it is shown in section 2.6 that, even given this weak definition of Budget-Balance, an optimal ownership structure is such that the net profit of each cooperative equals the transfers to its suppliers.

Finally, I define the Optimality Condition.

Definition of the Optimality Condition

Given that a profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Implementability Condition and the Budget-Balance Condition, T_i satisfies the Optimality Condition for the single-period model if and only if, given T_i , the vector of individually optimal bids, $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$, and the vector of cooperative capacities and investments, $(A_j^*, B_j^*)_{j \in M}$, which implements these bids, solve:

$$\text{MAX}_{(a_i, A_i, B_i)_{i \in Z}} \sum_{j \in M} P_j(A_j^*, B_j^*) - \sum_{i \in Z} C_i(a_i; \theta_i) .$$

This condition ensures that the profit-sharing rule T_i maximizes the joint income of all producers who supply a cooperative.

2.5 Conditions for an Optimal Profit-Sharing Rule

Using the definitions of section 2.4, I prove Proposition 1.

Proposition 1.

A profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Implementability Condition if and only if it satisfies the Unanimity Condition.

Proof Proposition 1.

If a profit-sharing rule satisfies the Unanimity Condition,

$(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$, satisfies:

1. $A_i^* = A^*, \forall i \in Z$
2. $B_i^* = B^*, \forall i \in Z$.

Given the assumption that the number of producers in the set Z approaches infinity, it must be shown that, for $\forall (\theta_i)_{i \in Z}$, there exists a vector $(A_j^*, B_j^*)_{j \in M}$, which implements $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}$, if and only if T_i satisfies the Unanimity Condition, where z denotes the number of producers in Z . The individually optimal bids of all producers in Z are not denoted by z , because these bids do not depend on the number of producers in Z , as is implied by Fact 1.

IF There are two ways to prove that a profit-sharing rule is implementable if it satisfies the Unanimity Condition under the assumption that the number of producers in Z approaches infinity. The first approach is to establish that a profit-

sharing rule is implementable if it satisfies the Unanimity Condition and if the number of producers in Z is infinite. The second approach is to establish that a coordinator can implement each producer's individually optimal bid with a probability which is arbitrarily close to one if the number of producers in Z approaches infinity. I pursue both approaches, in part IF A and IF B, respectively.

IF A I first show that a profit-sharing rule is implementable if it satisfies the Unanimity Condition and if the number of producers in Z is infinite. If T_i satisfies the Unanimity Condition, there is only one subset of producers, i.e.: $Z_S = Z$. To implement their individually optimal bids, the coordinator must build a number of cooperatives, each of which has a capacity A^* and an investment B^* , whose aggregate capacity is just sufficient to process the aggregate output of all producers in Z , if z equals ∞ . This means that he must find an integer, m_z^* , such that:

$$\sum_{i \in Z_z} a_i^* = m_z^* A^*, \text{ for } z = \infty,$$

where $(a_i^*, A^*, B^*; \theta_i)_{i \in Z_z}$ is the vector of individually optimal bids of all producers in Z_z if T_i satisfies the Unanimity Condition.

To show that m_z^* exists if z equals ∞ , define a positive integer m_z^* , such that:

$$m_z^* A^* \leq \sum_{i \in Z_z} a_i^* < (m_z^* + 1) A^* ,$$

for any large number of producers z . This number exists, since, given the requirements on T_i , $A^* < \infty$ and $a_i^* < \infty$.

In other words, m_z^* is such that the aggregate supply of all producers can be processed with the aggregate capacity of all cooperatives, except the supply of a rest group of producers whose joint supply is smaller than A^* .

Now, since $a_i^* > 0 \forall i \in Z_z$,

$$\frac{m_z^* A^*}{\sum_{i \in Z_z} a_i^*} \leq 1 < \frac{(m_z^* + 1) A^*}{\sum_{i \in Z_z} a_i^*} .$$

Furthermore, given that $A^* < \infty$, and $a_i^* > 0$

$$\frac{A^*}{\sum_{i \in Z_z} a_i^*} = 0 \text{ at } z = \infty .$$

Therefore,

$$\frac{m_z^* A^*}{\sum_{i \in Z_z} a_i^*} = 1 = \frac{(m_z^* + 1) A^*}{\sum_{i \in Z_z} a_i^*} , \text{ at } z = \infty .$$

Hence, if z equals ∞ , m_z^* satisfies:

$$\sum_{i \in Z_z} a_i^* = m_z^* A^* .$$

In other words, if the number of producers in Z is infinite and if the optimal capacity of each cooperative is finite, the coordinator must build an infinite number of cooperatives to accommodate all producers. In that case, the coordinator can accommodate all producers in cooperatives with a capacity which

equals the optimal capacity chosen by all producers, because the joint supply of the rest group of producers is smaller than the optimal capacity of one cooperative.

IF B Secondly, I show that the bids of all producers can be implemented with a probability which is arbitrarily close to one if the number of producers in Z approaches infinity.

Suppose that the coordinator randomly selects the bids which he will implement. As I explained in part IF A of this proof, the coordinator can always implement the bids of all producers if T_i satisfies the Unanimity Condition, except the bids of some rest group, whose aggregate individual output is less than the optimal capacity of one cooperative, by building a number of cooperatives m_z^* such that:

$$m_z^* A^* \leq \sum_{i \in Z_z} a_i^* < (m_z^* + 1) A^* ,$$

for any large number of producers z .

I denote the smallest individually optimal bid of all producers in Z_z as: $\min a_i^*$, which exceeds zero, given the definition of the set Z_z . Hence, for any given z , the greatest possible number of producers whose bid cannot be implemented equals:

$$\frac{A^*}{\min a_i^*} .$$

I denote the lower limit on the chance that a producer's bid will be implemented, given z , as p_z . Hence,

$$p_z \geq 1 - \frac{A^*}{z (\min a_i^*)}, \quad \forall i \in Z, z.$$

This implies that $\lim_{z \rightarrow \infty} p_z = 1$, since $\min a_i^* > 0$.

In other words, the chance that a producer's individually optimal bid can be implemented as the number of producers approaches infinity is arbitrarily close to one if T_i satisfies the Unanimity Condition. This concludes the IF section of the proof of Proposition 1.

ONLY IF: If T_i does not satisfy the Unanimity Condition, there exists some $(\theta_i)_{i \in Z}$, such that the individually optimal bid of some producer $i \in Z$ satisfies:

$$a_i^* > 0,$$

$$a_i^* \neq m_i A_i^*, \text{ for any integer } m_i, \text{ and}$$

$$(A_i^*, B_i^*) = (A_L^*, B_L^*),$$

while the optimal bid of another producer $j \neq i$, $j \in Z$ satisfies:

$$a_j^* > 0,$$

$$a_j^* \neq m_j A_j^* \text{ for any integer } m_j, \text{ and}$$

$$(A_j^*, B_j^*) = (A_H^*, B_H^*), \text{ and}$$

$$(A_L^*, B_L^*) \neq (A_H^*, B_H^*).$$

Since the individually optimal bid of each producer is unique, given his type, θ_i , the last inequality implies that $\theta_i \neq \theta_j$. Now call type θ_i " θ_L " if θ_i is such that $(A_i^*, B_i^*) = (A_L^*, B_L^*)$ and

call type θ_j " θ_H " if θ_j is such that $(A_j^*, B_j^*) = (A_H^*, B_H^*)$. Suppose that a set Z of producers is characterized by a vector of types $(\theta_L, (\theta_H)_{z-1})$. Clearly, the individually optimal bid of the one producer with type θ_L , $(a_L^*, A_L^*, B_L^*; \theta_L)$, cannot be implemented with positive probability, no matter how large z is, because $a_L^* \neq m_i A_L^*$ and $(A_L^*, B_L^*) \neq (A_H^*, B_H^*)$. Therefore, T_i is not implementable if it does not satisfy the Unanimity Condition. This concludes the proof of Proposition 1.

2.6. The Optimal Profit-Sharing Rule:

Proportional Profit-Sharing

In this section, I prove Proposition 2, which states that profit-sharing in proportion to patronage is optimal.

Proposition 2.

A profit-sharing rule $T_i(a_i, A_i, B_i)$ is optimal if and only if it has the following form:

$$T_i(a_i, A_i, B_i) = \frac{a_i}{A_i} [P_i(A_i, B_i) - rB_i],$$

where $P_i(A_i, B_i) - rB_i$ is the net profit of a cooperative which is characterized by the vector (A_i, B_i) , and where (a_i, A_i, B_i) is a bid submitted by a producer who supplies such a cooperative.

In other words, a profit-sharing rule is optimal if each producer receives a share of its net profit which equals his share of its patronage.

Proof

The proof of Proposition 2 proceeds as follows. I first prove that, if T_i has this form, the Unanimity Condition, the Budget-Balance Condition and the Optimality Condition are satisfied if all producers submit their individually optimal bids. Given Proposition 1, this establishes that T_i is optimal if it has the form stated above. Secondly, I prove that T_i satisfies the Unanimity Condition and the Budget-Balance

Condition only if it has the form stated above. This concludes the proof of Proposition 2.

IF If T_i has the form specified in Proposition 2, the first-order conditions which characterize the solution to each producer's individual optimization problem are:

$$\text{FOC}(a_i) \quad \frac{P_i - rB_i}{A_i} - C_i^a = 0,$$

$$\text{FOC}(A_i) \quad \frac{a_i}{A_i} \left[P_i^A - \frac{P_i - rB_i}{A_i} \right] = 0,$$

$$\text{FOC}(B_i) \quad \frac{a_i}{A_i} [P_i^B - r] = 0,$$

at $(a_i^*, A_i^*, B_i^*; \theta_i)$.

Given this profit-sharing rule, the Hessian of V_i has the following form at $(a_i^*, A_i^*, B_i^*; \theta_i)$:

$$\begin{bmatrix} -C_i^{aa} & 0 & 0 \\ 0 & \frac{a_i}{A_i} P_i^{AA} & \frac{a_i}{A_i} P_i^{AB} \\ 0 & \frac{a_i}{A_i} P_i^{BA} & \frac{a_i}{A_i} P_i^{BB} \end{bmatrix}$$

This matrix is negative definite, given the assumptions on C_i and P_j , since $a_i^* > 0$, $\forall i \in Z$. Furthermore, FOC's (a_i) and (A_i) imply that $a_i^* < \infty$ and $A_i^* < \infty$, given the restrictions on C_i and

P_j . Therefore, this profit-sharing rule satisfies the requirements on T_i specified in exhibit 1.

Furthermore, the vector (A^*, B^*) satisfies $FOC(A_i)$ and $FOC(B_i)$, $\forall i \in Z$. Hence, this profit-sharing rule also satisfies the Unanimity Condition. Given that T_i satisfies the Unanimity Condition, the vector of individually optimal bids of all producers in Z can be written as: $((a_i^*; \theta_i)_{i \in Z}, A^*, B^*)$. In that case, the Budget-Balance Condition can be restated as follows.

The Budget-Balance Condition Given the Unanimity Condition

Given that a profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Unanimity Condition, T_i satisfies the Budget-Balance Condition if and only if, $\forall (\theta_i)_{i \in Z}$,

$$\sum_{i \in Z} T_i = \frac{\sum_{i \in Z} a_i}{A} [P(A, B) - rB],$$

at $((a_i^*; \theta_i)_{i \in Z}, A^*, B^*)$.

Clearly, the profit-sharing rule T_i satisfies the restated Budget-Balance Condition.

Finally, I prove that T_i satisfies the Optimality Condition if it has the form stated above. Given that T_i satisfies the Unanimity Condition, the Optimality Condition can be restated as follows.

The Optimality Condition Given the Unanimity Condition

Given that a profit-sharing rule $T_i(a_i, A_i, B_i)$ satisfies the Unanimity Condition, T_i satisfies the Optimality Condition if and only if, $\forall (\theta_i)_{i \in Z}$, the vector of individually optimal bids, $((a_i^*; \theta_i)_{i \in Z}, A^*, B^*)$, solves:

$$\text{MAX}_{((a_i)_{i \in Z}, A, B)} \sum_{i \in Z} \left[\frac{a_i}{A} [P(A, B) - rB] - C_i(a_i; \theta_i) \right].$$

If the profit-sharing rule T_i has the form stated in Proposition 2, the first-order conditions which characterize the solution to this maximization problem are identical to the first-order conditions which characterize the solution to each producer's individually optimal bid, given T_i . Hence, this profit-sharing rule satisfies the Optimality Condition.

ONLY IF To derive the profit-sharing rule stated in Proposition 2 from the definition of an optimal profit-sharing rule, I first state the following two facts.

Fact 2.

For any profit-sharing rule T_i ,

$$\frac{\delta a_i}{\delta \theta_i} > 0,$$

at $(a_i^*, A_i^*, B_i^*; \theta_i)$.

This fact is established as follows. Implicitly differentiating the three first-order conditions of each producer's individual optimization problem, which are stated in section 2.3, the numerator of the above derivative equals $C_i^{a\theta}$, which is strictly smaller than zero by assumption. The denominator of this derivative equals:

$$- C_i^{aa} + [T_i^{aa} [T_i^{AA} T_i^{BB} - T_i^{AB} T_i^{BA}] - T_i^{aA} [T_i^{Aa} T_i^{BB} - T_i^{AB} T_i^{Ba}] + T_i^{aB} [T_i^{Aa} T_i^{BA} - T_i^{AA} T_i^{Ba}]] / [T_i^{AA} T_i^{BB} - T_i^{AB} T_i^{BA}],$$

which is strictly smaller than zero, given the restrictions on C_i and on T_i . (see exhibit 1) Therefore, a_i^* is a strictly increasing function of θ_i . This function is written as $a_i^*(\theta_i)$.

Fact 3.

If a profit-sharing rule satisfies the Unanimity Condition,

$$\frac{\delta A_i}{\delta \theta_i} = 0, \quad \frac{\delta B_i}{\delta \theta_i} = 0, \quad \forall i \in Z,$$

at $(a_i^*, A_i^*, B_i^*; \theta_i)$. These equalities are implied by the definition of the Unanimity Condition.

Furthermore, Fact 1 implies that, at $(a_i^*, A_i^*, B_i^*; \theta_i)$, the derivatives of a_i, A_i and B_i with respect to θ_j are zero.

Given these facts, the proof proceeds as follows. First, if T_i is optimal, it must satisfy the Budget-Balance Condition as restated above. Hence, the following equality must hold at $(a_i^*, A_i^*, B_i^*; \theta_i)_{i \in Z}, \forall (\theta_i)_{i \in Z}$:

Equality A.

$$\frac{\delta \sum T_i}{i\epsilon Z} = \frac{\delta \frac{\sum a_i}{A} [P - rB]}{\delta \theta_i}$$

Given Fact 3, the left-hand side of Equality A yields:

$$\frac{\delta \sum T_i}{i\epsilon Z} = T_i^a \frac{\delta a_i}{\delta \theta_i},$$

while the right-hand side of Equality A yields:

$$\frac{\delta \frac{\sum a_i}{A} [P - rB]}{\delta \theta_i} = \frac{P - rB}{A} \frac{\delta a_i}{\delta \theta_i}.$$

Therefore, the following equality holds at $(a_i^*, A_i^*, B_i^*; \theta_i)$,

$\forall(\theta_i)$:

Equality B.

$$T_i^a \frac{\delta a_i}{\delta \theta_i} = \frac{P - rB}{A} \frac{\delta a_i}{\delta \theta_i}$$

The integral over θ_i at $(a_i^*, A_i^*, B_i^*; \theta_i)$ of the left-hand side of Equality B equals:

$$\int_{\underline{\theta}_i}^{\theta_i} T_i^a \frac{\delta a_i}{\delta \theta_i} d\theta_i,$$

where $\underline{\theta}_i$ solves:

$$\text{MAX}_{\theta_i} \theta_i \quad \text{s.t.} \quad a_i^*(\theta_i) = 0.$$

Using Facts 2 and 3, this integral equals:

$$\int_0^{a_i^*} T_i^a da_i = T_i + Z_i', \quad \forall \theta_i \text{ at } (a_i^*, A_i^*, B_i^*; \theta_i).$$

Likewise, the integral over θ_i at $(a_i^*, A_i^*, B_i^*; \theta_i)$ of the right-hand side of Equality B equals:

$$\int_{\underline{\theta}_i}^{\theta_i} \frac{P - rB}{A} \frac{\delta a_i}{\delta \theta_i} d\theta_i .$$

Again, using facts 2 and 3, this integral equals:

$$\frac{a_i}{A_i} [P_i - rB_i] + Z_i', \forall \theta_i \text{ at } (a_i^*, A_i^*, B_i^*; \theta_i).$$

Combining these two integrals yields:

$$T_i = \frac{a_i}{A_i} [P_i - rB_i] + Z_i, \forall \theta_i \text{ at } (a_i^*, A_i^*, B_i^*; \theta_i).$$

Furthermore, Z_i equals zero, since $T_i(0, A_i, B_i)$ equals zero, given the requirements on T_i . Hence, the profit-sharing rule derived from the the requirements on T_i , the Unanimity Condition and the Budget-Balance Condition has the form stated in Proposition 2. This concludes the proof of Proposition 2.

2.7 Discussion

This section briefly describes three variations on the cooperative decision model presented above, which show how it applies to consumer cooperatives, to non-marketed investor-owned firms and to cooperatives with an open membership policy. It then discusses the implications of the results of this model for cooperatives.

Consumer Cooperatives

Although the results stated in this chapter were derived using a decision model of a cooperative whose members supply a product to it, they can easily be applied to the case of a cooperative whose members buy a product from it. To do so, assume that a member's utility is separable in money and in the product bought from the cooperative. A consumer's utility then equals: $V_i(a_i, A_i, B_i; \theta_i) = U_i(a_i; \theta_i) - T_i(a_i, A_i, B_i)$, where T_i is the consumer's share of the total cost of the cooperative from which he buys product a_i and U_i is his utility of consuming a_i , given his type, θ_i .

The cooperative's net cost of supplying A_j to its members, given its investment B_j , equal $C_j(A_j, B_j; \Phi) + rB_j$. If U_i is strictly concave in a_i and $-C_j$ is strictly quasi-concave in (A_j, B_j) , Propositions 1 and 2 apply directly to such a cooperative. In that case, the optimal cost-sharing rule is to share the cooperative's cost in proportion to each buyer's share of the cooperative's total sales to its members, i.e.:

$$T_i = \frac{a_i}{A_i} [C_i(A_i, B_i; \Phi) + B_i].$$

Non-Marketed Investor-Owned Firms

The results of this model also apply to an investor-owned firm whose owners choose not to trade its shares on the stock market, assuming that the investor's total utility is separable in money and in the cost of providing equity to the firm. In a mixed economy, such firms may include privately owned firms as well as firms in the public sector. In that case, a_i can be interpreted as each investor's equity contribution to the firm and $C_i(a_i; \theta_i)$ as his cost of providing this equity, given his investment alternatives, which are denoted by θ_i .

When applied to a non-marketed investor-owned firm, the results of this decision model suggest that, if the investors share the profit of this firm in proportion to their contribution to its equity, each investor will contribute an amount of equity to the firm, such that his marginal cost of providing equity equals the marginal return on equity of the firm, even if these investors have different investment alternatives. In addition, the investors will unanimously agree to issue a total amount of equity which maximizes the firm's return on equity.

This result appears to be analogous to the results of a model on shareholder unanimity by Grossman and Stiglitz [1980]. They prove that in a single-period model, the owners of a non-marketed investor-owned firm who choose the firm's policies and their own shares in each firm simultaneously, will unanimously agree to issue enough equity to maximize the value of each firm, provided that they share the firm's value in proportion to their contribution to its equity. They obtain this result by assuming that the so-called "spanning" and "competitiveness" assumptions hold. These assumptions hold if all firms produce only one product, profit, and if a firm's value equals its profit, as is assumed in the cooperative decision model.

Cooperatives with an Open Membership Policy

If the members of a cooperative adopt an open membership policy, they cannot choose the optimal size of its patronage. Instead, this patronage depends on the number of producers who choose to join the cooperative. As a result, the actual patronage of such a cooperative may not maximize the joint income of its members. This can be demonstrated as follows.

In terms of the cooperative decision model, a cooperative's patronage equals its capacity to process the product supplied to it by its members. If the members of a supplier-cooperative adopt an open membership policy and if they share its profit in proportion to patronage, each member earns:

$$V_i(a_i, B_i; \theta_i) = \frac{a_i}{a_i + a_{-i}^*} [P_i(a_i + a_{-i}^*, B_i) - rB_i] - C_i(a_i; \theta_i),$$

where a_{-i}^* denotes the individually optimal output supplied by all members of the cooperative, except producer i .

In that case, the first-order conditions which characterize each member's individually optimal bid, (a_i^*, B_i^*) , imply that, given a_{-i}^* , each producer's optimal output, a_i^* , is such that his marginal cost of producing an additional unit of output, C_i^a , does not equal the marginal profit of processing that additional unit, P_i^A , unless the total supply to the cooperative, $a_i + a_{-i}^*$, is such that the average net profit of the cooperative equals its marginal profit. If the members of the cooperative cannot choose its optimal capacity, this may not be the case. Hence, if the members of a cooperative adopt an open membership policy, the total patronage of the cooperative may not be optimal and as a result, they may not make efficient private production decisions.

Implications for Cooperatives

I have shown in this chapter that, given the assumptions of the cooperative decision model, the Coordination Problem can be resolved only by adopting profit-sharing in proportion to patronage, and that this method of profit-sharing resolves the Coordination Problem even if the members of a cooperative are not alike and if their characteristics cannot be observed. If this method of profit-sharing is adopted, the members of a

cooperative will unanimously agree to choose a cooperative capacity which maximizes the average profit per unit of product supplied to it and they will choose an investment which maximizes its total profit.

Furthermore, the private production decisions of each member are such that each member's marginal cost of production equals the marginal profit of the cooperative he supplies. These production decisions of the cooperative's members and the policies of the cooperative maximize the joint income of the members of that cooperative. The members will make these optimal choices, no matter whether they act individually or in a coalition and no matter what their characteristics are. These results obtain even if each cooperative has only a few members, as long as the total population of producers who supply cooperatives is very large.

This result has several implications for cooperatives. First, it suggests that the members of a cooperative should adopt a closed membership policy, to ensure that the cooperative will reach its optimal size. In that case, the cooperative's members will admit new members until the cooperative's profit per unit of patronage is maximized. This means that the members of cooperative determine whether to admit new members in much the same way as the shareholders of an investor-owned firm, who issue new equity until the market value of its shares is maximized.

This view of the role of membership policy of a cooperative contradicts that of Jesse et al [1982], who argue that a cooperative with a closed membership policy is more likely to abuse its market power than a cooperative with an open membership policy. I contend that a cooperative must adopt a closed membership policy to ensure that these policies, combined with the private production decisions of each member, maximize the joint income of the cooperative's members. In addition, I argue that, if a cooperative adopts an open membership policy, it is likely to pursue a strategy aimed at monopolizing the supply of its members' product and, if this strategy is successful, to maximize its members' profit by abusing the monopoly power it has gained. A cooperative with a closed membership policy, on the other hand, would not be able to exercise monopoly power, unless its optimal capacity would be close to the total output of all producers of that product.

Secondly, the results of this model suggest that each member's share of the cooperative's profit should equal his share of its patronage. In that case, the cooperative can admit both small and large members, as long as they trade the same type of product with the cooperative. This profit-sharing rule also implies that a cooperative's members share the cost of its equity in proportion to their share of its patronage. As noted by Knoeber and Baumer [1983], this resolves the free-rider problem of equity investment in cooperatives.

The result that profit-sharing in proportion to patronage is optimal for cooperatives confirms the intuition of earlier cooperative theorists, such as Meade [1972], who suggested this profit-sharing rule without proving that it ensures that members agree on the cooperative's optimal policies. However, this result contradicts the profit-sharing rules for cooperatives suggested by Zusman, Staatz and Sexton, who conclude that profit-sharing in proportion to patronage is generally suboptimal. This difference can be traced to differences in the assumptions underlying the decision models of these authors and the cooperative decision model presented above. Specifically, Zusman assumes that the members of a cooperative cannot choose the size of its total membership [p.221], Staatz assumes that the patronage of each member of the cooperative is fixed exogenously [p.1085] and Sexton assumes that the cooperative's members act as price-takers in their trade with the cooperative, even though they share its profit and determine its policies [p.215]. However, most cooperatives do in fact share their profit in proportion to patronage. It appears therefore that the limitations on the range of choices and the rationality of the members of a cooperative imposed by these authors do not reflect the actual behavior of the members of most cooperatives.

2.8 Alternative Assumptions

The cooperative decision model which is used in this chapter to prove that profit-sharing in proportion to patronage is optimal rests on a number of assumptions. In this section, I discuss a number of situations in which these assumptions may not be valid. This may cause disagreement among the cooperative's members, and it may reduce the cooperative's profit per unit of patronage. As a result, members may prefer to sell their product to investor-owned firms instead of establishing a cooperative, even if there is a lack of competition between these firms.

Number of Producers

If there is only a small number of producers who can supply cooperatives, the Unanimity Condition does not guarantee that each producer's bid can be implemented. As a result, these producers may not agree on the cooperative's optimal size or on its other policies. Such problems could be common in joint-ventures with a small number of potential participants. A similar problem occurs if all cooperatives are not equally profitable, even if their members choose the same cooperative policies, due to differences in the exogenous factor Φ_j between cooperatives.

Observability of Patronage

If it is not possible to observe how much each member supplies to his cooperative, the cooperative fits the description of a

public good given in chapter 1.2, and the cooperative decision model changes to one where each producer can submit a bid which only states the policies of the cooperative, (A_i, B_i) , but not his own supply (a_i) . Laffont and Maskin [1980] show that in that case no budget-balanced profit-sharing rule exists which yields a Strong Nash Equilibrium in Dominant Strategies for every set of types of the cooperative's members [theorem 5.1].

Product Homogeneity

If the product supplied by a cooperative's members is not homogenous, it may be impossible to determine how much each member's product contributes to the cooperative's total profit. For example, Holmstrom [1982] finds that, if it is impossible to determine how much the activity of each member of a team contributes to the team's profit, there does not exist a budget-balanced transfer mechanism which yields efficient production decisions by each member of that team. A similar problem occurs if the opportunity cost of equity, r , is not the same for all members of the cooperative.

A case study of the effects of product diversity on the ability of a cooperative to resolve the Coordination Problem is provided in chapter 4, which describes the merger negotiations between Land O'Lakes, Cenex and Farmland, three of the largest agricultural cooperatives in the United States. Land O'Lakes was a dairy processing and farm input supply

cooperative. Cenex was a farm input supply cooperative which distributed primarily petroleum products and Farmland was a diversified farm input supply cooperative which also processed meat.

The case explains that a merger between these three cooperatives was attractive for two reasons. First, it would increase the operational efficiency of these cooperatives in the short run. This was expected to generate \$60 million in annual cost savings, or about two-thirds of the cooperatives' joint profits in 1988. [ch 4:exh 10,21] Secondly, it would improve the cooperative's long-run ability to compete with private firms. In agribusiness, some giant global firms were buying up private farm input suppliers around the world. These global firms competed by using skills which they had acquired outside the farm input industry and by integrating their operations on a global scale. Other private firms were integrating vertically into farm input supply and food marketing, to reduce the cost or improve the quality of the specialized products they marketed [ch 4:p 1-3,exh 4,5]. By merging, the cooperatives hoped to improve their ability to compete with these private firms, because the merger would leverage their product development and their joint distribution network and because it would enable them to exploit the synergies between food marketing and farm input supply [ch 4:p 10-11].

In spite of these advantages, three successive rounds of merger negotiations between the three cooperatives broke down between 1986 and 1989. The case points to three possible explanations for the failure of these cooperatives to merge. First, it appeared that the negotiation process did not build sufficient trust between the participants [ch 4:p 13,14]. Secondly, the short-term cost savings were distributed very unevenly among the three firms. Farmland and Cenex were expected to increase their combined profits by 78% if the merger would go through, while Land O'Lakes would increase its profitability by only 23% [ch 4:exh 10,21].

The last, and major, reason was that the three cooperatives disagreed on the future structure of the merged cooperative [ch 4:p 10-11]. The main cause of this disagreement was that these cooperatives were serving different constituencies. Land O'Lakes, on the one hand, was owned both by dairy farmers, which supplied their milk to it, and by farm input retail cooperatives, which bought farm inputs from Land O'Lakes. [ch 4:exh 15] The dairy farmers shared the profit of Land O'Lakes' food marketing activities, while the farm input cooperatives shared the profit from its farm input supply activities. To protect the interests of these two owner groups, Land O'Lakes had separated the profit and equity accounts for these two activities. This ensured that Land O'Lakes dairy farmers would not have to subsidize an investment in Land O'Lakes farm input supply activities and vice versa. [ch 4: Appendix] Farmland

and Cenex, on the other hand, were owned by farm input retail cooperatives only, who shared the profit of Farmland and Cenex in proportion to their patronage of each of these two cooperatives, respectively. Hence, these cooperatives did not need to separate the equity accounts of each of their activities. [ch 4:p 8-9]

The board of directors of Land O'Lakes felt that the merged cooperative should have an ownership structure like that of Land O'Lakes, to ensure that the profit of Land O'Lakes profitable dairy marketing activities would accrue to Land O'Lakes dairy farmers and that they could not be used to finance investments in activities which would not profit these farmers. However, Farmland's management felt that such a structure would impede the ability of the merged cooperative to finance investments in activities where it wanted to expand with profits from other activities. [ch 4:p 12]

Thus, the case suggests that, if a cooperative is owned by groups of owners which trade different products with it, there is a trade-off between the cooperative's ability to resolve the coordination problem, by sharing the profit earned in each activity only among the members who trade the product which is used in that activity, and the cooperative's ability to exploit the synergies between its various activities, which enhances its ability to compete with integrated private firms. Investor-owned firms do not have this problem, because they

are owned by only one group of shareholders, who have the single and common objective to maximize shareholder value.

Competition of the Cooperative with its Members

If a cooperative competes with some of its members, there may be a conflict of interest between members in whose markets the cooperative competes and members in whose markets it does not compete. In the cooperative decision model presented in this chapter, this problem could be represented by adding an assumption that the type of a member of a cooperative, θ_j , depends on the cooperative's policies, B_j .

To prevent such conflict, a cooperative's members often bar their cooperative from markets in which they compete themselves. However, this may reduce the profitability of the cooperative. A case study which illustrates this problem is provided in chapter 5, which describes the Cooperative Company Friesland (CCF), a major Dutch dairy cooperative which produces and markets condensed milk worldwide. CCF was owned cooperatively by five dairy cooperatives in The Netherlands, each of which produced a range of dairy products themselves, primarily for the European market.

Until 1985, CCF had been very profitable. [ch 5:exh 23] As a result, it paid its owners a much higher net milk price than they could earn by processing milk themselves. [ch 5:exh 19] However, after 1985, CCF's profitability declined sharply. In

1987, it lost \$20 million. [ch 5:p 1] As a result, its net milk price declined to a level below the price its member cooperatives could earn by processing milk themselves.

According to CCF's management, these problems were caused primarily by adverse developments on the market for condensed milk. Demand for condensed milk declined, both in Europe and worldwide, and the industry was plagued by overcapacity, because many suppliers had invested in new plants between 1980 and 1985. [ch 5:p 4-5] This decline of the attractiveness of the market for condensed milk contrasted with opportunities for growth and greater profitability on the European market for specialty dairy products. [ch 5:p 2-3,exh 1,7,8] Several private and cooperative competitors of CCF had pursued very profitable strategies in this market segment. [ch 5:exh 14,15]

The case suggests that one of the underlying reasons for CCF's decline in profitability was that CCF's management had not recognized the impending decline of the market for condensed milk, because CCF's mission on the European market had been restricted to marketing condensed milk products. [ch 5:p 8] This restriction prevented it from competing in other markets of the European dairy market even though its technological and marketing skills which it could use to compete in these markets appeared to be superior to those of its member cooperatives. [ch 5:p 6-7]

Thus, this case suggests that a cooperative's ability to diversify into profitable market segments may be restricted by the fact that some of its members already operate in those markets. An investor-owned firm does not face such restrictions, because its owners do not compete with the firm.

Inobservable Effort of Cooperative Members

In some cases, the inobservable effort of members of the cooperative can improve the profitability of their cooperative. In terms of the cooperative decision model presented in this chapter, this would imply that the exogenous factor $\bar{\phi}_j$ depends on the private effort of one of its members, a_i . This problem was noted by Helmberger [1966], among others.

An example of this problem is provided in the case study in chapter 6, which describes the New Zealand Dairy Board, the dairy export marketing organization in New Zealand which was owned cooperatively by New Zealand's 22 dairy cooperatives.

The Board's objective was to increase the value of New Zealand's milk by increasing its exports of specialty dairy products. [ch 6:p 1] To achieve this objective, the Board pursued a global marketing strategy. The Board had increased its investments in foreign subsidiaries from \$19 million in 1980 to \$414 million in 1988 [ch 6:p 4] In addition, it was delegating the responsibility for coordinating marketing

programs and for identifying new market opportunities to its subsidiaries. [ch 6:p 7]

Although this strategy was very successful [ch 6:exh 14,15], New Zealand's milk price nevertheless declined by 43% between 1981 and 1987, as a result of a general decline the world market price for dairy products in that period. To improve New Zealand's milk price, the Dairy Board had structured its relations with the member cooperatives, to achieve two goals. First, it wanted to coordinate the production of specialty dairy products in New Zealand by the member cooperatives with the market opportunities identified by its overseas subsidiaries. To achieve this coordination, the Board had implemented a pricing structure which made the member cooperatives indifferent between the various dairy products they could produce. This enabled the Dairy Board to allocate the production of dairy products to each of the dairy cooperatives. [ch 6:p 8]

Secondly, the Board wanted to stimulate its member cooperatives to acquire the technological and management skills which were necessary to produce specialty dairy products and to make incremental improvements in these products. The Board's management felt that such private efforts by the member cooperatives would enable the Board to compete more successfully in the market for specialty dairy products. The Board had introduced certain price incentives,

it subsidized their R&D effort and it improved the flow of communication between the dairy cooperatives and the Board's subsidiaries. [ch6:p 8-9]

Despite this encouragement however, too few dairy cooperatives had acquired these skills. [ch 6:p 9] The case explains that the main reason for this was that the price mechanism which the Board used to coordinate the production decisions of the member cooperatives provided insufficient incentives to these cooperatives to invest in acquiring these skills. [ch 6:p 9]

Thus, the case suggests that, if the producer-members of a cooperative can improve its profitability by their private effort, there is a trade-off between the cooperative's ability to stimulate such activity by each member and its ability to coordinate their private decisions to maximize the joint profits from marketing their products cooperatively. This coordination problem arises because the cooperative's members own their production facilities privately, while they own the cooperative jointly. This problem does not arise in an integrated investor-owned firm, because one group of shareholders owns all production and marketing facilities.

CHAPTER THREE: THE HORIZON PROBLEM AND PATRONAGE RIGHTS

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3.1. Introduction

The Horizon Problem concerns the question how a cooperative's present members can capture its future profits which are due to their past investments in the cooperative if they reduce their share of its patronage before these investments have paid off. If the cooperative's members do not capture these profits, they will underinvest in their cooperative. This reduces their joint income. In this chapter, I prove that the Horizon Problem can be resolved by creating a market for the right to use the cooperative, using a variation on the cooperative decision model of chapter 2.

This chapter is organized as follows. Section 2 first describes the Horizon Problem and it describes how cooperatives have tried to resolve it. It then describes what patronage rights are and it explains how they can resolve the Horizon Problem, if demand for these rights is competitive. It also describes a few other benefits of creating a market for such rights. This section is in place of a discussion at the end of this chapter. Section 3 first introduces a variation of the cooperative decision model described in chapter 2 with two periods. In this model, a cooperative's present members can make an investment which may increase the cooperative's present and future profits. Section 3 defines and identifies an optimal ownership structure for such a cooperative. In this structure, the present members of a cooperative earn the cooperative's future profit which is due to their investment

in the cooperative. Section 4 compares three ownership structures, with revolving equity, with fixed patronage shares and with patronage rights, respectively. This section shows that an ownership structure with fixed patronage shares and an ownership structure with patronage rights is optimal if a cooperative's investment pays off over several periods and if the cooperative's members change their share of its patronage between these periods, while an ownership structure with revolving equity is not optimal under those circumstances. Section 5 compares an ownership structure with revolving equity and with patronage rights. It shows that, if the future payoff of a cooperative's investment is uncertain, an ownership structure with patronage rights is optimal, while a structure with revolving equity is not. Finally, section 6 argues that, if a cooperative adopts patronage rights, it can attract outside equity as cheaply as an investor-owned firm and it can structure its management incentives as efficiently, even if its members can manipulate its profit.

3.2 The Horizon Problem and Patronage Rights

3.2.1. The Horizon Problem

An often-cited disadvantage of the cooperative form of ownership is that a cooperative cannot raise as much equity as an investor-owned firm. [LeVay, 1983, p.30, USDA, 1987, p.39] One cause of this problem may be that a cooperative's cost of attracting equity from investors who do not supply the cooperative is higher than the cost of attracting equity for an investor-owned firm, if a cooperative's members can manipulate its profit at the expense of outside investors who share this profit, as is explained in section 3.6. In that case, the cost of equity of a cooperative is higher than that of an investor-owned firm, if the cooperative's members are more wealth-constrained or risk-averse than outside investors. Another cause may be that a cooperative's members do not want to invest as much equity in their cooperative as the owners of an investor-owned firm, even if they are equally risk-averse or wealth-constrained. This can be explained as follows.

Suppose that a cooperative has made an investment in some asset which pays off over a certain period. Suppose furthermore that each member's share of the cost of this asset equals his share of the cooperative's patronage. Suppose also that each member's share of the profit of the cooperative in each period equals his share of its patronage in that period. Finally, suppose that a member's share of the cooperative's

patronage decreases during the period in which an asset which the cooperative has invested in pays off. This may be the case, for example, because his production efficiency relative to that of new members of the cooperative declines.

In that case, this member's share of the cost of the cooperative's present investment is larger than his share of the cooperative's future profit, which is generated by this investment. This reduces the member's return on his investment in the cooperative. As a result, he wants to invest less in the cooperative than he would if his share of its patronage remained constant or increased. If the members whose share of the cooperative's patronage decreases over time are the majority in the cooperative, they will invest too little in the cooperative, unless there exists some mechanism which transfers the cooperative's future profits which are due to its past investments to its present members. This problem, which I refer to as the Horizon Problem, is recognized in the literature on cooperatives and labor-managed firms. [See for example Jensen and Meckling, 1979, p.481, McGregor, 1977, p.480]. Obviously, the reverse problem would occur if the members whose share of the cooperative increases during the time that an asset pays off are in the majority.

The Horizon Problem and Intangible Assets

The cooperative Horizon Problem does not arise if a cooperative's investment pays off only in the period in which

its cost is incurred. In that case, a cooperative's members will make optimal decisions concerning the cooperative's investment if each member's share of the cooperative's profit in the period that such an investment pays off and his share of the cost of that investment in that period equals his share of the cooperative's patronage in that period, as was shown in chapter 2.

As is explained in section 3.4.1, the members of a cooperative can ensure that they share the cost of an investment in proportion to their share of its patronage in the period that this cost is incurred by adopting an ownership structure with profit-sharing in proportion to patronage and with revolving equity. Hence, such an ownership structure is optimal for an investment which pays off only in the period that its cost is incurred.

However, if a cooperative has adopted an ownership structure with profit-sharing in proportion to patronage and revolving equity and if some of its members reduce their share of the cooperative's patronage over time, the Horizon Problem described above arises for investments in two types of assets. First, suppose that an investment in some asset pays off over several periods. In that case, the members of a cooperative with revolving equity will disagree on the optimal size of the cooperative's investment in such an asset, as is shown in section 3.4.1. More specifically, such a cooperative will

underinvest in an asset which pays off after its cost has been incurred, if most of the cooperative's members plan to reduce their share of the cooperative's patronage before the cooperative's investment in this asset has paid off.

Secondly, suppose that the members of a cooperative must choose the size of a cooperative's investment in some asset before they know how much this investment will increase the cooperative's future profits with certainty and that they can choose their own output level and the cooperative's capacity once they know how these decisions will affect the cooperative's profit with certainty. In that case, the cooperative's members will disagree on the optimal size of the cooperative's investment in such an asset, even if this asset pays off only in one period and if the cooperative's members share its cost in proportion to their actual share of its patronage in that period. This is demonstrated in section 3.5.2. More specifically, the cooperative will underinvest in such an asset if most of the cooperative's present members expect that their share of the cooperative's patronage will be relatively low if the asset's payoff is relatively high.

One type of asset which pays off after its cost has been incurred is an asset which is expensed when it is acquired. One such asset is an intangible asset, for example product and market development. The payoff of such an asset also tends to be very uncertain. Hence, the above arguments suggest that, in

a cooperative with profit-sharing in proportion to patronage and revolving equity, the Horizon Problem may arise for intangible assets. Of course, the Horizon Problem may arise for certain types of tangible assets as well. Because an ownership structure with revolving equity and profit-sharing in proportion to patronage does not resolve the Horizon Problem for an investment in intangible assets, such a cooperative is likely to invest relatively little in such assets, compared to a private firm which competes in the same industry.

To support my hypothesis that cooperatives with profit-sharing in proportion to patronage and revolving equity tend to underinvest in intangible assets, I quote Mr. De Boer, the Chairman of CCF. In referring to the members of the dairy cooperatives which owned CCF, he expressed this problem as follows: "Farmers are not willing to make in-depth investments in their cooperatives. They think in terms of the milk price of today and not about investing in building a market position which will yield a cash-flow eight years from now." [ch 5:p 6] In addition, Mr. R.L. Fogg, vice president of Land O'Lakes Inc. has been quoted as follows: "A farmer is very happy to invest in a plant. That's tangible. For the same \$10 million, he doesn't feel too good about a guy from New York with suede shoes running an ad campaign." [Brown, 1988]

I emphasize that these quotes by themselves do not prove or disprove the hypothesis that cooperatives tend to underinvest in intangible assets. Unfortunately however, it would be difficult to test this hypothesis empirically, not least because cooperatives are privately held firms, which do not disclose their investments in intangible assets. Moreover, even if it were possible to prove empirically that cooperatives invest relatively little in intangible assets, there might be other causes for this, such as risk aversion of the cooperative's members.

To resolve the Horizon Problem for intangible assets, cooperatives could adopt an ownership structure in which each member's share of a cooperative's patronage is fixed over time, as is shown in section 3.4.2. For example, the Cooperative Company Friesland, which is described in chapter 5, had adopted such an ownership structure to protect each member's share of the profits generated by its past investments in developing its overseas markets for condensed milk.

As is argued in section 3.4.2 however, such an ownership structure has two disadvantages. First, the members of a cooperative cannot allocate their product efficiently between the cooperative and its alternative uses if the transaction cost of trading this product is high. Secondly, in an ownership structure with fixed patronage shares, there is no

market for the right to supply the cooperative. If a cooperative would create such a market, the market price for such a right would provide an objective measure of the value of supplying the cooperative instead of another firm. Therefore, an ownership structure with fixed patronage shares does not have the advantages associated with such a market, which are described in section 3.2.2.

3.2.2 Patronage Rights

Description of Patronage Rights

Another approach to resolving the Horizon Problem is to create a market for patronage rights. This alternative is described in this section.

A patronage right is a perpetual right to supply a certain volume of product from the cooperative which has issued this right, or to buy a certain volume from it. Each right entitles its owner to one share of the cooperative's equity and to one vote in its governance. The owner of a patronage right can sell this right to another member of the cooperative or to a new patron, thereby transferring the right to supply the cooperative and his share of its ownership. The cooperative's members can jointly decide to issue more patronage rights or to buy back these rights at their market price.

To create a competitive market for patronage rights, a cooperative can adopt certain rules regarding the trade in these rights and the disclosure of information about the cooperative to members and nonmembers. Such rules would include regulations concerning the purchase of the cooperative's patronage rights by private investors who do not supply the cooperative themselves. In addition, it could appoint an independent third party to enforce these rules. If many cooperatives would adopt patronage rights, a "Cooperative

Exchange" might evolve, similar to a stock exchange, on which these rights would be traded.

An Example of the Market Valuation of a Patronage Right

If demand for patronage rights is competitive, a buyer of a patronage right is willing to pay a price for this right which equals the difference between the price he expects to receive if he sells his product to the cooperative and the price he can earn if he sells his product to another firm, times the product volume per patronage right, plus the profit he expects the cooperative to retain, per patronage right. The following numerical example illustrates how this price is determined.

In this example, the cooperative has issued 10 units of patronage rights to its members. Each right represents 10 units of product supplied to the cooperative by its members. Hence, the product volume supplied by the cooperative's members equals 100 units. This cooperative has made an investment of \$100 in tangible and intangible assets, some of which is represented by equity on its balance sheet and some of which has been expensed.

The net present value of the cooperative's total expected future profits is the cooperative's "profit". This profit equals the net present value of the cooperative's total expected future revenues minus the expected future costs of all inputs and of borrowed capital, except the cost of the

product supplied to the cooperative by its members and the cost of the equity which has been provided by them. One part of this profit is paid out to its members as a price for the product they supply to the cooperative in the future and the other part is retained, for example to finance future investments. The part of the cooperative's profit which is paid to its members, divided by the volume of product supplied to the cooperative, is the "price paid out per unit of product" while the part of the cooperative's profit which is retained, divided by the number of patronage rights, is the "retained profit per patronage right".

In the example, there are two scenarios: a good future and a bad future. In a good future, the cooperative earns a profit of \$1300 and the profit paid out per unit of product is \$11. Hence, the retained profit per patronage right is \$20. In a bad future, the cooperative makes a profit of \$1000 and the profit paid out per patronage right is \$9. Hence, the retained profit per patronage right is \$10. In both scenarios, a buyer of a patronage right can sell his product to another firm for \$10. Hence, a buyer is willing to pay a price of \$30 for the cooperative's patronage right in a good future and \$0 in a bad future.

Example Market Valuation of Patronage Rights

	<u>Good Future</u>	<u>Bad Future</u>
Number of patronage rights	10	10
Product volume	100	100
Equity invested in the cooperative	\$100	\$100
Profit	\$1300	\$1000
- paid out	\$1100	\$900
- retained	\$200	\$100
Profit paid out per unit of product	\$11	\$9
Price paid by competitor	\$10	\$10
	---	---
Price difference	\$1	-\$1
Price difference per patronage right	\$10	-\$10
Profit retained per patronage right	\$20	\$10
	---	---
Market price of a patronage right	\$30	\$0

This example suggests that the market price of a patronage right could be less than zero. However, if the cooperative's members have no obligation to supply their product to the cooperative, they will prefer not to use their patronage rights if the market price of these rights falls below zero. In that case, their patronage rights are worthless. Thus, a member's liability to losses incurred by the cooperative per patronage right equals the market price of such a right. If a cooperative issues patronage rights which carry an obligation to supply the cooperative and which can be sold back to the cooperative at a penalty, a member's total liability per patronage right equals the market price of that right plus this penalty.

Advantages of Patronage Rights

If demand for patronage rights is competitive, the market for these rights benefits the members of a cooperative in much the same way as the stock market benefits the owners of an investor-owned firm. As the example above illustrates, the market price of such a right incorporates the cooperative's future profits which are due to its past investments, whether these investments are intangible or not. Hence, patronage rights resolve the Horizon Problem. Section 3.4.3 shows that an ownership structure with patronage rights resolves the Horizon Problem if a cooperative's investment pays off over several periods, no matter when its cost is incurred. Section 3.5.2 shows that such an ownership structure with patronage rights also resolves the Horizon Problem if the cooperative's present members are not certain how their investment in the cooperative will affect its future profits. Because a cooperative which adopts patronage rights resolves the Horizon Problem, its members are more willing to provide equity to the cooperative, for example for investments in intangible assets.

In addition to resolving the Horizon Problem, an ownership structure with patronage rights has a number of other advantages. First, patronage rights may strengthen the balance sheet of the cooperative's members, by recognizing the market value of their investment in their cooperative. If the cooperative invests in intangibles, this market value will exceed the book value of the member's share of the

cooperative's equity, which is his only asset in the cooperative if it adopts an ownership structure with equity revolvment instead of patronage rights.

Secondly, patronage rights may enable the cooperative to attract outside equity as cheaply as an investor-owned firm and to structure its management incentives as efficiently, even if the cooperative's members can manipulate its profit. This can be achieved by tying the cooperative's management incentives and the dividends paid to outside investors to the market price of the cooperative's patronage rights, instead of to the cooperative's profit. This enables a cooperative to compete more successfully in activities which require an investment in assets which cannot be collateralized and whose profitability depends on management's inobservable effort, including investment in intangible assets.

This argument is explained in section 3.6. If the dividends paid by a cooperative to outside investors and its management incentives depend on its profit, the members of that cooperative may increase their income at the expense of outside investors and management. They can do this by lowering the quality of the product they supply to the cooperative. Although this may reduce the profit of the cooperative, it may reduce their cost of supplying the cooperative even more. If the cooperative's dividends and its management incentives depend on the market price of its patronage rights instead of

on its profit, the cooperative's members cannot raise their income at the expense of the outside investors or its management, because this market price depends on the profit per unit of product supplied to the cooperative minus the cost of supplying that product. Hence, if a cooperative's members raise their income by lowering the quality of the product they supply to the cooperative, the market price of a patronage right increases, even though the cooperative's profit per unit of patronage may be reduced.

Finally, patronage rights may facilitate mergers between cooperatives or privatization of a cooperative. Such restructuring may help discipline a cooperative's management, just as the stock market disciplines the management of an investor-owned firm. [Walkling and Long, 1984] Again, such discipline is especially important in activities where it is difficult to monitor management effort directly. Patronage rights facilitate such restructuring as follows. If there exists a market for patronage rights, another cooperative or a private investor can simply tender for the patronage rights of the cooperative. This eliminates the need for elaborate negotiations between the cooperative's owners and the buyer to value the cooperative's assets and to align their policies. The case study on the merger negotiations between Farmland, Cenex and Land O'Lakes in chapter 4 demonstrates that, without a market for patronage rights, disagreement about the structure of the merged cooperative between the negotiators

can prevent a merger between their cooperatives, even if it benefits all parties.

In summary, patronage rights may improve the willingness of its members to provide equity to the cooperative and it reduces the cost of attracting equity from outside investors. In addition, patronage rights may improve the cooperative's ability to structure its management incentives as efficiently as an investor-owned firm and to restructure its operations by mergers and privatization. However, if demand for patronage rights is not competitive, their market price may be less than the future value of supplying the cooperative instead of another firm. In that case, these rights may not fully resolve the cooperative Horizon Problem and the other benefits derived from creating a market for these rights are reduced as well. However, even if the market for patronage rights is not competitive, a cooperative's members may well be better off if there exists a market for patronage rights which enables them to capture some of the future profits generated by their past investments than if no such market exists.

Examples of Patronage Rights

A simplified form of an ownership structure with patronage rights is found in some country clubs, whose members are allowed to sell their membership through the club to prospective members at its actual market price when they leave the club. This form is also common among professional

partnerships, particularly those where partners' equity invested in the firm is substantial, such as partner-owned investment banks. Three examples of agricultural cooperatives which have adopted patronage rights are: Mississippi Chemical Company (MCC), AVEBE, a Dutch potato processing cooperative, and the National Grape Growers Association. These examples suggest that, in principle, it is possible to create a market for patronage rights.

In the case of AVEBE, the potato farmers who owned its patronage rights were obliged to supply the cooperative, but they could sell a right back to the cooperative at a penalty of Hfl 1,500. The market price of AVEBE's patronage rights varied between Hfl -1,500 in 1982, when prospects for the processed potato market were bad, and Hfl 3,000 to Hfl 4,000 in 1988, when this market had turned around. [ch 5:p 17] In the case of the National Grape Growers Association, which owned Welch Foods, the cooperative's patronage rights were tied to a member's grape vine acreage. Members could transfer their rights to other grape growers with permission of the cooperative. As a result, the value of the land of member grape growers exceeded the land value of non-members by \$1,000 per acre. [Goldberg, 1972] However, it seems more practical to link patronage rights to a specific product volume rather than to the acreage used to grow this product, as this enables members to convert their land to another purpose without losing their patronage right. Obviously, if the members of a

cooperative are firms which do not operate land themselves, as is the case for Mississippi Chemical, [ch 4:p 18] patronage rights should be tied to the product the members trade with the cooperative.

The Future of Cooperatives and Patronage Rights

Despite the apparent advantages of patronage rights, few agricultural cooperatives have adopted them. One reason for this may be that, for some cooperatives, demand for patronage rights would never be fully competitive, because there is a sunk cost to becoming a supplier of the cooperative. Another reason may be that the cooperative's management has better information than its members concerning the potential improvements in the cooperative's profitability which could be achieved if the cooperative adopted patronage rights, and that management opposes the adoption of patronage rights, because it increases its members' ability to control their performance. The final reason, and in my view the most compelling one, is that in the past, many agricultural cooperatives have led a cozy existence in markets which were protected by regulatory barriers, with little competition from investor-owned firms.

However, the markets agricultural cooperatives compete in are changing rapidly, due to three developments. First, the three case studies included in this thesis suggest that the most profitable opportunities in the markets which agricultural

cooperatives compete in are in the segments for products which are specialized to the needs of a particular customer group. To compete successfully in these market segments, cooperatives need to invest in intangible assets like product and market development [Ch 4:p 2; Ch 5:p 2, exh 1,7,14,15; Ch 6:p 3,6]. Secondly, some of the barriers which used to protect the markets that agricultural cooperatives compete in are being removed. Examples are the reduction of import barriers in Japan's agricultural markets and the planned removal of all internal market barriers in the EEC by 1992. Finally, investor-owned firms increasingly integrate vertically into activities which have traditionally been controlled by agricultural cooperatives. Examples of this development in the United States are the poultry and hog industries. [ch 4:p 3]

In the past, cooperatives have responded to these developments by attracting equity from non-members to invest in intangible assets. As is mentioned in section 3.6, some cooperatives have established joint-ventures with a private firm to attract such equity. However, such joint-ventures usually result in a loss of control of the cooperative's members over the activities of the cooperative which have been placed in the joint-venture, to avoid the moral hazard problem associated with joint ownership of such a venture by the cooperative's members and the private firm. As a result, the joint-venture could behave in the same way as a private firm towards the members of the cooperative.

I conclude that, in order to survive under these changing market conditions without losing control over their cooperative, the members of agricultural cooperatives must adopt a more innovative ownership structure. Such a structure should enable the cooperative to attract equity more cheaply from its members and outside investors to invest in intangible assets and it should enable it to reward and discipline its management more efficiently. As is explained in this section, an ownership structure with patronage rights satisfies these requirements. Therefore, I expect that more agricultural cooperatives will adopt patronage rights in the future.

3.3 The Optimal Ownership Structure in a Two-Period Model

This section first describes a two-period cooperative decision model, in section 3.3.1. This model is then used in sections 3.3.2 and 3.3.3 to define and identify an ownership structure which resolves the Horizon Problem. In section 3.3.4, I specify a test which can be used to determine whether an ownership structure resolves the Horizon Problem. This test is based on the conditions which characterize the capacity and the investment of a cooperative under the optimal ownership structure identified in section 3.3.3.

As is mentioned in section 3.2.1, the Horizon Problem may occur in two sets of circumstances. First, it arises if the cooperative's investment pays off over several periods and if the share of the cooperative's patronage of the majority of its members is reduced between those periods. This situation is captured in the two-period model presented in this section, by assuming that the profit of a cooperative in both periods depend on its initial investment and by assuming that a member's production efficiency, or type, may change between these two periods.

Secondly, the Horizon Problem may arise if the cooperative's members are uncertain how their investment in the cooperative will affect their incomes when they choose this investment, while they can choose its capacity and their own output levels when they are certain how these decisions will affect their

incomes. Section 3.5.2 describes a variation of the two-period model which captures this situation.

3.3.1. The Two-Period Cooperative Decision Model

Technology and Market Conditions

The cooperative decision model described in this section has two periods: period 1, the present, and period 2, the future. Suppose that there is a very large population of producers, Γ . A producer in Γ is denoted by the subscript i .

In period 1, a producer can produce a volume a_{i1} at a cost $C_{i1}(a_{i1}; \theta_{i1})$, which depends on his output, given his type in period 1, θ_{i1} . Cooperative j in period 1 has a total capacity of A_{j1} , which equals the total product volume supplied to it by its members. As in the single-period model, it is assumed that the cooperative's capacity can be financed entirely with debt. In addition, the cooperative can make an investment in certain tangible and intangible assets, which may increase the profit of the cooperative. This investment is financed in part with equity, which must be provided by the cooperative's members. The cooperative's equity investment in period 1 is B_j . The cooperative's profit, $P_{j1}(A_{j1}, B_j; \bar{\phi}_{j1})$ depends on its capacity and on its investment, given its production technology and the market conditions in period 1, which are given by $\bar{\phi}_{j1}$. I assume that $\bar{\phi}_{j1}$ has the same value, $\bar{\phi}_1$, for all cooperatives.

In period 2, some producers are incumbents, who also produced some output in period 1 and others are new producers. A producer's cost of production in period 2, $C_{i2}(a_{i2};\theta_{i2})$, depends on his output, a_{i2} , given his type in period 2, θ_{i2} . The type of an incumbent producer in period 2 may be smaller, equal or greater than his type in period 1. I assume that θ_{i2} is independent of θ_{i1} . However, it can be shown that the ownership structure identified in section 3.3.3 is also optimal if θ_{i2} is a function of θ_{i1} . I assume that a producer knows in period 1 what his type in period 2 will be. This assumption is dropped in section 3.5.

The producers in period 2 can supply two kinds of cooperatives. Cooperatives which have been built in the first period are called "old" cooperatives and cooperatives which are built in the second period are called "new" cooperatives. An old cooperative is denoted by the subscript j_0 and a new cooperative is denoted by the subscript j_n . The profit of an old cooperative, $P_{j_0}(A_{j_0};B_j,\Phi_{j_0})$ depends on its processing capacity A_{j_0} , given B_j , the cooperative's investment in period 1, and Φ_{j_0} , its technology and market conditions in period 2. The profit of a new cooperative, $P_{j_n}(A_{j_n};0,\Phi_{j_n})$, depends on its processing capacity, A_{j_n} , given that its investment in period 1 equals zero, and given its processing and market conditions, Φ_{j_n} . I assume that there is no opportunity to invest in either an old or a new cooperative in period 2. I also assume that Φ_{j_0} and Φ_{j_n} have the same value for all

cooperatives in period 2, Φ_2 . For convenience, Φ_1 and Φ_2 are dropped from the notation for the remainder of this chapter, except in section 3.5.

The assumptions concerning the investment opportunities of cooperatives in period 1 and period 2 are inconsistent, in the sense that a new cooperative in period 2 cannot invest in period 2 and earn some payoff from that investment in that period, in the same way as an old cooperative can in period 1. However, it can be shown that the optimal ownership structure which is identified in section 3.3.3 is also optimal if both old and new cooperatives can make an investment in period 2.

I assume that a producer's costs of production in both periods, C_{i1} and C_{i2} , and the profits of old and new cooperatives in both periods, P_{j1} , P_{j0} and P_{jn} , have the same properties as those specified in the single-period model for C_i and P_j , respectively (see exhibit 1). Specifically, I assume that the profit of an old cooperative in period 2 is strictly quasi-concave in (A_{j0}, B_j) and that the profit of a new cooperative in period 2 is strictly concave in A_{jn} . Hence, the maximum profit a producer can earn per unit of product if he supplies a new cooperative is less than the maximum profit per unit of product he can earn if he supplies an old cooperative in period 2, as long as the investment in the old cooperative is greater than zero. I assume that all producers

have the same time preference of income. The value of the production costs of all producers and the profits of all cooperatives in both periods given above are the net present values of these costs and these profits at the beginning of period 1.

The Bidding Procedure

The game coordinator in the two-period model has the same objective as in the single-period model: to maximize the income of all suppliers of cooperatives in period 1 and 2, subject to the constraints that the producer's bids in both periods must be implementable and that the aggregate transfers paid to these producers equal the aggregate profits of all cooperatives.

Given these objectives, the bidding procedure is summarized as follows. In period 1, a producer can choose his own output level in period 1 as well as the capacity of the cooperative he supplies in period 1 and the capacity of that cooperative in period 2. In addition, he chooses the investment of that cooperative in period 1. In period 2, a producer can choose his own output level in period 2 and the capacity of a new cooperative in period 2.

A producer in period 1 submits a bid $(a_{i1}, A_{i1}, A_{i0}, B_i)$. If he submits this bid, he must supply his output in period 1, a_{i1} , to one or more cooperatives, each of which has a capacity of

A_{i1} in period 1 and A_{i0} in period 2 and an investment of B_j . In exchange, that producer receives $T_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i)$. Hence, his income in period 1, $V_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i; \theta_{i1})$, equals $T_{i1} - C_{i1}$.

A producer in period 2 submits a bid (a_{i2}, A_{in}) . If he submits this bid, he must supply his output in period 2, a_{i2} , to an old cooperative, with capacity A_{i0} and investment B_i or to a new cooperative, with capacity A_{in} . If a producer in period 2 did not produce any output in period 1, his output can be allocated to any old cooperative, or to a new cooperative with capacity A_{in} . In exchange, he receives $T_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i)$. Hence, a producer's income in period 2, $V_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i, \theta_{i2})$, equals $T_{i2} - C_{i2}$.

Instead of the bidding procedure in period 2 mentioned above, the game coordinator could ask each producer to submit a bid which states how much he wants to supply to an old cooperative in period 2, (a_{i0}) and how much he wants to supply to a new cooperative (a_{in}) . However, it can be shown that, both in the bidding procedure described above and in this alternative procedure, the optimal ownership structure of a cooperative is such that all producers in period 2 are indifferent between supplying an old or a new cooperative in period 2. Hence, the bidding procedure used in this section is appropriate.

The next subsection describes how the game coordinator implements the bids of all producers in period 1 and 2, and how he allocates the output of each producer in period 2 to the old and the new cooperatives which have a capacity and an investment of his choice. As in the single-period model, I assume that the game coordinator is wealthy, so that he can pay the transfers $T_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i)$ and $T_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i)$ to a producer, even if he cannot implement his bids $(a_{i1}, A_{i1}, A_{i0}, B_i)$ and (a_{i2}, A_{in}) . However, as is stated in section 3.3.2, I require that an optimal profit-sharing rule is such that, in equilibrium, the game coordinator can implement the bids of all producers in both periods and that the aggregate transfers paid to these producers equal the aggregate profits of all cooperatives. Hence, the game coordinator does not incur any expenses in equilibrium. In the remainder of this subsection, I describe the equilibrium which is used to formally define the conditions on an optimal ownership structure in section 3.3.2.

A producer's individually optimal bid in period 1,

$(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})$, solves:

$$\text{MAX}_{(a_{i1}, A_{i1}, A_{i0}, B_i)} V_{i1} + V_{i2}(a_{i2}^*, A_{in}^*),$$

where (a_{i2}^*, A_{in}^*) solves:

$$\text{MAX}_{(a_{i2}, A_{in})} V_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i, \theta_{i2})$$

A producer's individually optimal bid in period 2,

$(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$, solves:

$$\text{MAX}_{(a_{i2}, A_{in})} V_{i2}(a_{i2}, A_{in}; a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*, \theta_{i2}).$$

I require that T_{i1} and T_{i2} have the following properties.

1. T_{i2} is twice continuously differentiable and strictly concave in A_{in} and quasi-concave in (a_{i2}, A_{in}) , at a producer's individually optimal bid $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$.
2. $(T_{i1} + T_{i2})$ is twice continuously differentiable and strictly quasi-concave in $(A_{i1}, A_{i0}, B_i, A_{in})$ and quasi-concave in $(a_{i1}, a_{i2}, A_{i1}, A_{i0}, B_i, A_{in})$ at a producer's individually optimal bid in period 1 and 2, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})$ and $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$.
3. $T_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i) = 0$ if $a_{i1} = 0$.
4. $T_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i) = 0$ if $a_{i2} = 0$.
5. $T_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i) = T_{i2}(a_{i2}, A_{in})$ if $a_{i1} = 0$.
6. T_{i1} and T_{i2} are such that, for $\forall(\theta_{i1})_{i \in Z1}$ and $\forall(\theta_{i2})_{i \in Z2}$, the elements a_{i1}^* , A_{i1}^* and A_{i0}^* of each producer's individually optimal bid in period 1 and the elements a_{i2}^* and A_{in}^* of each producer's individually optimal bid in period 2 are finite.

Properties 1 and 2 ensure that each producer's individually optimal bid in period 1 and in period 2 is unique. Properties 3 and 4 reflect the assumption that, in each period, the coordinator cannot pay a transfer to producers who do not supply a cooperative. Property five ensures that a producer who supplies a cooperative in period 2 but who does not produce any output in period 1 is indifferent about the

characteristics of an old cooperative he may supply in period 2 (see "Bid Implementation" below). Property 6 ensures that producers' individually optimal bids in period 1 and 2 can be implemented if the number of producers in both periods approaches infinity. Properties 3, 4 and 5 imply that $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})$ is independent of θ_{i2} if a_{i2}^* equals zero and that $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$ is independent of θ_{i1} if a_{i1}^* equals zero.

The subset Z_1 of Γ contains all producers whose individually optimal bids in period 1 satisfy: $a_{i1}^* > 0$ and $a_{i1}^* \neq m_{i1} A_{i1}^*$, for $\forall i \in Z_1$ and for any positive integer m_{i1} . I assume that the number of producers in Z_1 approaches infinity. The vector of individually optimal bids of all producers in Z_1 is:

$$(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z_1}.$$

A coalitionally optimal bid of some coalition in period 1, $C_1 \subset Z_1$, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in C_1}$, solves:

$$\text{MAX}_{(a_{i1}, A_{i1}, A_{i0}, B_i)_{i \in C_1}} \sum_{i \in C_1} [V_{i1} + V_{i2}(a_{i2}^*, A_{in}^*)],$$

where $\sum_{i \in C_1} V_{i2}(a_{i2}^*, A_{in}^*)$ solves:

$$\text{MAX}_{(a_{i2}, A_{in})_{i \in C_1}} \sum_{i \in C_1} V_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i, \theta_{i2}).$$

The vector of coalitionally optimal bids of a set D_1 of mutually exclusive coalitions of all producers in Z_1 is:

$$(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2}, D_1)_{i \in Z_1}.$$

The set Z_2 is a subset of Γ which contains all producers whose individually optimal bids in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i2})$, satisfy: $a_{i2}^* > 0$ and $a_{i2}^* \neq m_{in} A_{in}^*$, for $\forall i \in Z_2$ and for any positive integer m_{in} . I assume that the number of producers in Z_2 approaches infinity. The vector of individually optimal bids of all producers in Z_2 is: $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z_2}$.

A coalitionally optimal bid of some coalition in period 2, $C_2 \subset Z_2$, $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in C_2}$, solves:

$$\text{MAX}_{(a_{i2}^*, A_{in}^*)_{i \in C_2}} \sum_{i \in C_2} v_{i2}.$$

The vector of coalitionally optimal bids of a set D_2 of mutually exclusive coalitions of all producers in Z_2 is: $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2}, D_2)_{i \in Z_2}$. These definitions can be used to state Fact 4, as follows.

FACT 4 The vector of individually optimal bids of all producers in period 1, $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z_1}$, and period 2, $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z_2}$, form a Subgame-Perfect, Strong Nash Equilibrium in Dominant Strategies, which is defined as follows:

1. $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z_2}$ solves:

$$\text{MAX}_{(a_{i2}^*, A_{in}^*)_{i \in C_2}} \sum_{i \in C_2} v_{i2}, \forall C_2 \subset Z_2, \forall (a_{j2}^*, A_{jn}^*; \theta_{j1}, \theta_{j2})_{j \in C_2, j \in Z_2}$$

2. $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z_1}$ solves:

$$\text{MAX}_{(a_{i1}, A_{i1}, A_{i0}, B_i)_{i \in C1}} \sum_{i \in C1} V_{i1} + V_{i2}(a_{i2}^*, A_{in}^*),$$

where $\sum_{i \in C1} V_{i2}(a_{i2}^*, A_{in}^*)$ solves:

$$\text{MAX}_{(a_{i2}, A_{in})_{i \in C1}} \sum_{i \in C1} V_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i, \theta_{i2}),$$

$$\forall C1 \subset Z1, \forall (a_{j1}, A_{j1}, A_{j0}, B_j; \theta_{j1}, \theta_{j2})_{j \in C1, j \in Z1}.$$

I refer to the definition of the Strong Nash Equilibrium in Dominant Strategies for the single-period model in chapter 2.3 for an explanation of this definition.

Proof

This proof is similar to the proof of Fact 1 in chapter 2.3. First, by definition of T_{i2} and C_{i2} , the individually optimal bid of a producer in period 2 is unique and it is independent of the bids of all other producers in both periods. Secondly, the first-order conditions which characterize the individually optimal bid of each member of a coalition $C2 \subset Z2$ are identical to the first-order conditions which characterize the unique, coalitionally optimal bid of that coalition. The same argument applies to the individually optimal bid of a producer in period 1, given the definition of T_{i1} , T_{i2} , C_{i1} and C_{i2} .

Fact 4 implies that all producers in period 1 and 2 will submit their individually optimal bids, whatever the bids of all other producers are and no matter whether they submit their bids individually or in a coalition.

Bid Implementation

In period 1, the bids of all producers are implemented with a procedure which is very similar to the procedure used in the single-period model. This procedure is defined below.

Definition Bid Implementation in Period 1

The vector of capacities and investments of old cooperatives, $(A_{j1}^*, A_{j0}^*, B_j^*)_{j \in M1}$, implements the vector of individually optimal bids in period 1, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$ if and only if, for each subset $Z1_s \subset Z1$, there is a subset $M1_s \subset M1$, such that:

1. $(A_{i1}^*, A_{i0}^*, B_i^*) = (A_{j1}^*, A_{j0}^*, B_j^*)$, $\forall i \in Z1_s, \forall j \in M1_s$,
2. $\sum_{i \in Z1_s} a_{i1}^* = \sum_{i \in M1_s} A_{j1}^*$,

where the subset $Z1_s$ is defined as:

$$(A_{i1}^*, A_{i0}^*, B_i^*) = (A_{s1}^*, A_{s0}^*, B_s^*), \forall i \in Z1_s,$$

$$(A_{i1}^*, A_{i0}^*, B_i^*) \neq (A_{s1}^*, A_{s0}^*, B_s^*), \forall i \notin Z1_s,$$

and where the subset $M1_s$ is defined as:

$$(A_{j1}^*, A_{j0}^*, B_j^*) = (A_{s1}^*, A_{s0}^*, B_s^*), \forall j \in M1_s,$$

$$(A_{j1}^*, A_{j0}^*, B_j^*) \neq (A_{s1}^*, A_{s0}^*, B_s^*), \forall j \notin M1_s.$$

The bidding procedure in period 2 differs from the one described above, because the coordinator must accommodate producers in both old and new cooperatives in period 2. To describe this procedure, I first define the subset $Z0$ of all producers in period 2 who were also producers in period 1. $Z0 \subset Z2$ is such that:

$$a_{i1}^* > 0, \forall i \in Z0.$$

Secondly, I define the subset Z_r of all producers in period 2 who do not increase their share of the patronage of their old cooperative between period 1 and period 2, if they submit their individually optimal bid. $Z_r \subset Z_2$ is such that:

$$a_{i1}^* > 0, \forall i \in Z_r,$$

$$\frac{a_{i1}^*}{A_{i1}^*} \geq \frac{a_{i2}^*}{A_{i0}^*}, \forall i \in Z_r.$$

By definition, Z_r is a subset of Z_0 . The complement of Z_r is the subset Z_e . Producers in Z_e are either new producers in period 2 or they are incumbent producers who would expand their share of the patronage of their old cooperative between period 1 and period 2, if they would continue to supply only their old cooperative. $Z_e \subset Z_2$ is such that:

$$\text{either: } a_{i1}^* = 0,$$

$$\text{or: } \frac{a_{i1}^*}{A_{i1}^*} < \frac{a_{i2}^*}{A_{i0}^*}, \forall i \in Z_e.$$

Given the definitions of these subsets, the coordinator's procedure of implementing each producer's individually optimal bid in period 2 is described as follows. First, the coordinator allocates the individually optimal output of each producer in the subset Z_r to the old cooperative which he supplied in period 1. By definition of this subset, the aggregate output in period 2 of all producers in Z_r who supplied a certain cooperative in period 1 is less than the capacity of that old cooperative in period 2. Secondly, the coordinator allocates as much of the optimal output of each

producer in the subset Z_e who is also in the subset Z_o to the old cooperatives which have a capacity of his choice and he allocates the rest of his output to the new cooperatives which have a capacity of his choice.

Finally, the coordinator allocates as much of the optimal output of all producers in the subset Z_n to the old cooperatives in period 2, to fully use their aggregate capacity, and he allocates the rest of their output to the new cooperatives which have a capacity of their choice. This method of bid implementation implies that only producers in the subset Z_e ever supply a new cooperative in period 2. After defining this procedure below, I explain under what conditions this bid implementation procedure is feasible.

Definition of Bid Implementation in Period 2

The vector $((A_{j_o}^*)_{j \in M_1}, (A_{j_n}^*)_{j \in M_n})$ implements $(a_{i_2}^*, A_{i_n}^*; \theta_{i_1}, \theta_{i_2})_{i \in Z_2}$ if and only if, for each pair of subsets $Z_{o_s} \subset Z_o$ and $Z_{e_s} \subset Z_e$, there exists a pair of subsets $M_{o_s} \subset M_1$ and $M_{n_s} \subset M_n$, such that:

1. $A_{i_o}^* = A_{j_o}^*$, $\forall i \in Z_{o_s}$ and $\forall j \in M_{o_s}$,
2. $A_{i_n}^* = A_{j_n}^*$, $\forall i \in Z_{e_s}$ and $\forall j \in M_{n_s}$,
3. $\sum_{i \in (Z_{o_s} \cap Z_{e_s})} a_{i_2}^* \leq \sum_{j \in M_{o_s}} A_{j_o}^* + \sum_{j \in M_{n_s}} A_{j_n}^*$,
4. $\sum_{i \in (Z_{o_s} \cup Z_{e_s})} a_{i_2}^* \geq \sum_{j \in M_{o_s}} A_{j_o}^* + \sum_{j \in M_{n_s}} A_{j_n}^*$,
5. $\sum_{i \in Z_2} a_{i_2}^* = \sum_{j \in M_o} A_{j_o}^* + \sum_{j \in M_n} A_{j_n}^*$,

where the subsets Zo_s , Ze_s , Mo_s and Mn_s are defined as follows. First, $Zo_s \subset Zo$ satisfies:

$$A_{io}^* = A_{so}^*, \forall i \in Zo_s, \text{ and}$$

$$A_{io}^* \neq A_{so}^*, \forall i \notin Zo_s.$$

Secondly, $Ze_s \subset Ze$ satisfies:

$$A_{in}^* = A_{sn}^*, \forall i \in Ze_s \text{ and}$$

$$A_{in}^* \neq A_{sn}^*, \forall i \notin Ze_s.$$

Thirdly, $Mo_s \subset Ml$ satisfies:

$$A_{jo}^* = A_{so}^*, \forall j \in Mo_s, \text{ and}$$

$$A_{jo}^* \neq A_{so}^*, \forall j \notin Mo_s.$$

Finally, $Mn_s \subset Mn$ satisfies:

$$A_{jn}^* = A_{sn}^*, \forall j \in Mn_s, \text{ and}$$

$$A_{jn}^* \neq A_{sn}^*, \forall j \notin Mn_s.$$

Conditions 1 and 2 ensure that all producers in period 2 supply an old or a new cooperative of their choice. Condition 3 ensures that the joint aggregate capacity of all old cooperatives with capacity A_{so}^* and all new cooperatives with capacity A_{sn}^* is at least as large as the aggregate output of all producers in period 2 who want to supply either an old cooperative with capacity A_{so}^* or a new cooperative with capacity A_{sn}^* . Condition 4 ensures that the joint aggregate capacity of all old cooperatives with capacity A_{so}^* and all new cooperatives with capacity A_{sn}^* is not larger than the aggregate output of all producers in period 2 who want to supply an old cooperative with capacity A_{so}^* plus the aggregate output of all producers in period 2 who want to supply a new

cooperative with capacity A_{sn}^* . Condition 5 ensures that the aggregate capacity of all old and new cooperatives equals the aggregate optimal output of all producers in period 2.

This bid implementation procedure in period 2 is feasible if two conditions are satisfied. First, T_{i1} and T_{i2} must be such that, if the number of producers in $Z1$ and $Z2$ approaches infinity, there exists a vector of capacities of old and new cooperatives which implements the vector of individually optimal bids of all producers in period 1 and 2. This condition is ensured by the definition of an optimal ownership structure given in section 3.3.2. Secondly, some new cooperatives must always be built in period 2. This condition is satisfied if T_{i1} and T_{i2} are such that a_{i2}^* , A_{i0}^* and A_{in}^* are finite, which is one of the requirements on T_{i1} and T_{i2} stated at the beginning of this section, and if the number of producers in period 22 is so large that, if their individually optimal bids are implemented, their aggregate output is at least as large as the aggregate capacity of the old cooperatives in period 2:

$$\sum_{i \in Z2} a_{i2}^* \geq \sum_{j \in M1} A_{j0}^*, \text{ for } \forall z2 \geq x, \text{ where } x \text{ is a finite integer.}$$

This requirement ensures that the total available capacity of all old cooperatives in period 2 is fully utilized. I assume that this requirement is satisfied for the remainder of this section. This assumption is analogous to the assumption in section 3.4 that demand for the right to use an old cooperative in period 2 is competitive.

3.3.2. Definition of an Optimal Ownership Structure

This section defines an optimal ownership structure in the framework of the two-period cooperative decision model, which is characterized by the profit-sharing rules in period 1 and 2, T_{i1} and T_{i2} .

Definition of an Optimal Ownership Structure

In the two-period cooperative decision model, an ownership structure (T_{i1}, T_{i2}) is optimal if and only if T_{i1} and T_{i2} satisfy the following three conditions.

1. T_{i1} and T_{i2} satisfy the Implementability Condition for the two-period model. For $\forall (\theta_{i1})_{i \in Z1}$ and $\forall (\theta_{i2})_{i \in Z2}$, there exists a vector $(A_{j1}^*, A_{jo}^*, B_j^*)_{j \in M1}$ and a vector $(A_{jn}^*)_{j \in Mn}$ which implements the vectors of individually optimal bids in period 1 and 2: $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$, and $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z2}$.

2. T_{i1} and T_{i2} satisfy the Budget-Balance Condition for the two-period model. For $\forall (\theta_{i1})_{i \in Z1}$ and $\forall (\theta_{i2})_{i \in Z2}$,

$$\sum_{i \in Z1} T_{i1}(a_{i1}, A_{i1}, A_{io}, B_i) + \sum_{i \in Z2} T_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{io}, B_i) \\ = \sum_{j \in M1} [P_{j1}(A_{j1}, B_j) + P_{jo}(A_{jo}; B_j) - rB_j] + \sum_{j \in Mn} P_{jn}(A_{jn}; 0),$$

at the vectors of individually optimal bids in period 1 and 2, $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$ and $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z2}$, and at the vectors of cooperative capacities and investments, $(A_{j1}^*, A_{jo}^*, B_j^*)_{j \in M1}$ and $(A_{jn}^*)_{j \in Mn}$, which implement these bids.

3. T_{i1} and T_{i2} satisfy the Optimality Condition for the two-period model, given that they satisfy the Implementability Condition and the Budget-Balance Condition stated above. For $\psi(\theta_{i1})_{i \in Z1}$ and $\psi(\theta_{i2})_{i \in Z2}$, the vectors of individually optimal bids in period 1 and 2, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$ and $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z2}$, and the vectors of cooperative capacities and investments, $(A_{j1}^*, A_{j0}^*, B_j^*)_{j \in M1}$ and $(A_{jn}^*)_{j \in Mn}$, which implement these bids, solve:

$$\begin{aligned} & \text{MAX} \\ & ((a_{i1}, A_{i1}, A_{i0}, B_i)_{i \in Z1}, (a_{i2}, A_{in})_{i \in Z2}) \\ & \sum_{j \in M1} [P_{j1}(A_{j1}, B_j) + P_{j0}(A_{j0}, B_j) - rB_j] + \sum_{j \in Mn} P_{jn}(A_{jn}, 0) \\ & - \sum_{i \in Z1} C_{i1}(a_{i1}; \theta_{i1}) - \sum_{i \in Z2} C_{i2}(a_{i2}; \theta_{i2}). \end{aligned}$$

These conditions can be explained as follows. The Implementability Condition requires that, given T_{i1} and T_{i2} , the individually optimal bids of all producers in period 1 and 2 can be implemented, given the assumption that the number of producers in period 1 and 2 approaches infinity. This condition is equivalent to the Unanimity Condition for period 1 and 2, as is shown in in section 3.3.3. The Unanimity Condition is defined as follows.

Definition of the Unanimity Condition

The profit-sharing rules T_{i1} and T_{i2} satisfy the Unanimity Condition for the two-period model if and only if:

A. For $\forall(\theta_{i1}, \theta_{i2})_{i \in Z1}$ the vector of individually optimal bids of all producers in $Z1$, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$, satisfies: $A_{i1}^* = A_1^*$, $A_{i0}^* = A_0^*$ and $B_i^* = B^*$, $\forall i \in Z1$.

B. For $\forall(\theta_{i1}, \theta_{i2})_{i \in Z2}$, the vector of individually optimal bids of all producers in $Z2$, $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z2}$, satisfies: $A_{in}^* = A_n^*$, $\forall i \in Z2$.

Secondly, the Budget-Balance Condition requires that T_{i1} and T_{i2} are such that the aggregate profits of all cooperatives in period 1 and 2 equal the aggregate transfers to all producers in these two periods. This Budget-Balance Condition implies that producers in period 1 may share in the profit of a cooperative in period 2 and vice versa. For example, in the optimal ownership structure identified in the next section, the suppliers of an old cooperative in period 1 earn the profit of their cooperative in period 2 which is due to their investment in the cooperative in period 1.

Finally, the Optimality Condition requires that T_{i1} and T_{i2} are such that the individually optimal bids of all producers in period 1 and 2 maximize their joint income, on the condition that these bids can be implemented and that the transfers to all producers are budget-balanced. It is shown in part 3 of the proof of proposition 3 that this condition is satisfied if T_{i1} and T_{i2} satisfy the Unanimity Condition and the Budget-Balance Condition.

3.3.3 The Optimal Cooperative Ownership Structure

Proposition 3.

In the two-period cooperative decision model, an ownership structure (T_{i1}, T_{i2}) is optimal if and only if the profit-sharing rules $T_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i)$ and $T_{i2}(a_{i2}, A_{in}; a_{i1}, A_{i1}, A_{i0}, B_i)$ are as follows:

$$1. T_{i1} = \frac{a_{i1}}{A_{i1}} [P_{i1}(A_{i1}, B_i) - rB_i + P_{i0}(A_{i0}, B_i) - A_{i0} \frac{P_n(A_n^*; 0)}{A_n^*}]$$

$$2. T_{i2} = \frac{a_{i2}}{A_{in}} P_{in}(A_{in}; 0),$$

where A_n^* is the bid on the capacity of a new cooperative of all producers $j \in Z_e$, $j \neq i$, and where $P_i(A_i, B_i)$ denotes the profit of a cooperative with a capacity and an investment equal to the capacity and the investment stated in the bids submitted by the producers who share its profit.

In this definition, A_n^* is independent of producer i 's bid to ensure that T_{i1} is defined, even if the bid of a producer in Z_e deviates from the bid A_n^* of all other producers in Z_e .

This proposition claims that, in an optimal ownership structure, all producers in period 2 receive a transfer equal to the profit per unit of product supplied to a new cooperative, times the volume of their individual production in period 2. This implies that the suppliers of a new cooperative in period 2 share its net profit in proportion to their share of its patronage. The suppliers of an old

cooperative also share its net profit in proportion to their share of its patronage. The net profit of an old cooperative in period 2 equal its gross profit, $P_{jo}(A_{jo};B_j)$, minus a fee which the suppliers of that cooperative in period 2 pay to its suppliers in period 1. This fee equals:

$$P_{io}(A_{io};B_i) - \frac{A_{io}}{A_{in}} P_{in}(A_{in};0) ,$$

which is equal to the profit of an old cooperative in period 2 minus the profit the suppliers of that cooperative in period 2 can earn if they supply a new cooperative in period 2 instead. This fee is the profit of an old cooperative in period 2 which is due to the equity investment in that cooperative in period 1. Finally, the suppliers of a cooperative in period 1 share the profit of that cooperative in period 1, plus the fee paid by its suppliers in period 2, minus the cost of the cooperative's investment, in proportion to their share of its patronage in period 1.

Proof Proposition 3.

This proof consists of three parts. Part 1 proves that T_{i1} and T_{i2} satisfy the Implementability Condition if and only if they satisfy the Unanimity Condition for the two-period model. Part 2 proves that T_{i1} and T_{i2} satisfy the Unanimity Condition and the Budget-Balance Condition if and only if they have the form stated in Proposition 3. Part 3 proves that T_{i1} and T_{i2} satisfy the Optimality Condition if they have the form stated in Proposition 3.

Part 1. Equivalence of Implementability and Unanimity

This proof is similar to the proof of Proposition 1 in chapter 2. Part 1A of this proof establishes that there exists a vector of capacities and investments of the old cooperatives in period 1 and period 2 which implements the individually optimal bids of all producers in period 1 if and only if T_{i1} and T_{i2} satisfy condition (A) of the Unanimity Condition for the two-period model. Part 1B establishes that, given that T_{i1} and T_{i2} satisfy condition (A) of the Unanimity Condition for the two-period model, there exists a vector of capacities of new cooperatives in period 2 which implements the individually optimal bids of all producers in period 2 if and only if T_{i1} and T_{i2} satisfy condition (B) of the Unanimity Condition for the two-period model.

1A. I first prove that, given the assumption that the number of producers in period 1 approaches infinity, there exists a vector of capacities and investments of the old cooperatives in period 1 and 2 which implements the individually optimal bids of all producers in period 1, if and only if T_{i1} and T_{i2} satisfy condition (A) of the Unanimity Condition for the two-period model.

IF If a profit-sharing rule satisfies condition (A) of the Unanimity Condition for the two-period model, the vector of

individually optimal bids of all producers in period 1,

$(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$, satisfies:

$A_{i1}^* = A_1^*$, $A_{i0}^* = A_0^*$ and $B_i^* = B^*$, $\forall i \in Z1$.

To implement these bids, the coordinator must build a number of cooperatives, each of which is characterized by the vector (A_1^*, A_0^*, B^*) , whose aggregate capacity in period 1 is sufficient to accommodate the aggregate output of all producers in $Z1$, given that the number of producers in $Z1$ approaches infinity.

This means that he must find an integer m_{1z}^* s.t.

$$\sum_{i \in Z1z} a_{i1}^* = m_{1z}^* A_{i1}^*, \text{ where } (a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1z}$$

is the vector of individually optimal bids of all producers in $Z1z$ and where z denotes the number of producers in $Z1$. It was shown in part B of the proof of Proposition 1 in chapter 2.4 that this integer exists if the number of producers in $Z1$ is infinite. Furthermore, the proof of Proposition 1 in chapter 2.4 implies that, if T_{i1} and T_{i2} satisfy condition (A) of the Unanimity Condition for the two-period model, the coordinator can implement each producer's individually optimal bid with a probability which is arbitrarily close to one as the number of producers in $Z1$ approaches infinity, if he randomly selects the bids which he will implement. Hence, T_{i1} and T_{i2} satisfy the Implementability Condition for the vector of individually optimal bids of all producers in $Z1$ if T_{i1} and T_{i2} satisfy condition (A) of the Unanimity Condition.

ONLY IF If T_{i1} and T_{i2} do not satisfy condition (A) of the Unanimity Condition for the two-period model, there exists some $(\theta_{i1})_{i \in Z1}$, such that the individually optimal bid of some producer $i \in Z1$ satisfies:

$$a_{i1}^* > 0,$$

$$a_{i1}^* \neq m_{i1} A_{i1}^* \text{ for any integer } m_{i1}, \text{ and}$$

$$(A_{i1}^*, A_{i0}^*, B_i^*) = (A_{L1}^*, A_{L0}^*, B_L^*),$$

while the optimal bid of another producer $j1 \neq i1$, satisfies:

$$a_{j1}^* > 0,$$

$$a_{j1}^* \neq m_{j1} A_{j1}^* \text{ for any integer } m_{j1}, \text{ and}$$

$$(A_{j1}^*, A_{j0}^*, B_j^*) = (A_{H1}^*, A_{H0}^*, B_H^*), \text{ and}$$

$$(A_{L1}^*, A_{L0}^*, B_L^*) \neq (A_{H1}^*, A_{H0}^*, B_H^*).$$

Since the individually optimal bid of each producer is unique, given his type in period 1 and period 2, $(\theta_{i1}, \theta_{i2})$, the last inequality implies that $(\theta_{i1}, \theta_{i2}) \neq (\theta_{j1}, \theta_{j2})$. Now denote producer i 's individually optimal bid by "L" if $(A_{i1}^*, A_{i0}^*, B_i^*) = (A_{L1}^*, A_{L0}^*, B_L^*)$ and denote producer's j 's individually optimal bid by "H" if $(A_{j1}^*, A_{j0}^*, B_j^*) = (A_{H1}^*, A_{H0}^*, B_H^*)$. Now suppose that a set $Z1$ of producers is characterized by a vector of types $((\theta_{L1}, \theta_{L2}), (\theta_{H1}, \theta_{H2})_{z-1})$. Clearly, the bid of the one producer with type $(\theta_{L1}, \theta_{L2})$ cannot be implemented with positive probability, no matter how large z is, because $a_{L1}^* \neq m_{i1} A_{L1}^*$ and $(A_{L1}^*, A_{L0}^*, B_L^*) \neq (A_{H1}^*, A_{H0}^*, B_H^*)$. Therefore, if T_{i1} and T_{i2} do not satisfy condition (A) of the Unanimity Condition, they do not satisfy the Implementability Condition for the two-period model.

1B I now prove that, given that T_{i1} and T_{i2} satisfy part (A) of the Unanimity Condition for the two-period model, and given that the number of producers in period 2 approaches infinity, there exists a vector of capacities of new cooperatives which implements the vector of individually optimal bids of all producers in period 2, if and only if T_{i1} and T_{i2} satisfy part (B) of the Unanimity Condition for the two-period model.

1E If T_{i1} and T_{i2} satisfy part (B) of the Unanimity Condition for the two-period model, the vector of individually optimal bids of all producers in period 2 who are in the set Z_e ,

$(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z_e}$ satisfies:

$$A_{in}^* = A_n^* \quad \forall i \in Z_e.$$

Then, given that T_{i1} and T_{i2} satisfy part (A) of the Unanimity Condition for the two-period model, T_{i1} and T_{i2} satisfy the Implementability Condition for the vector of individually optimal bids in period 2 if there exists a vector of capacities of old and new cooperatives, $((A_o^*)_{j \in M_1}, (A_n^*)_{j \in M_n})$ which implements the vector of individually optimal bids of all producers in period 2, given that the number of producers in Z_2 approaches infinity. This means that he must find an integer m_{nz}^* such that:

$$\sum_{i \in Z_{2z}} a_{i2}^* = [m_1^* A_o^* + m_{nz}^* A_n^*], \text{ where}$$

$(a_{i2}^*, A_n^*; \theta_{i1}, \theta_{i2})_{i \in Z_{2z}}$ is the vector of individually optimal bids of all producers in Z_2 , and where z denotes the number of producers in Z_2 , where m_1^* is the number of old cooperatives

built in period 1 and m_{nz}^* is the number of new cooperatives built in period 2. m_1^* and m_{nz}^* are both positive integers. I prove below that, given the number of cooperatives built in period 1, the integer m_{nz}^* exists if the number of producers in period 2 is infinite. To prove that m_{nz}^* exists, take a positive integer number of new cooperatives, m_{nz}^* , such that, for some large number z of producers in period 2:

$$m_1^* A_o^* + m_{nz}^* A_n^* \leq \sum_{i \in Z_{2z}} a_{i2}^* < m_1^* A_o^* + [m_{nz}^* + 1] A_n^*.$$

This number exists, because, by the assumption stated at the end of section 3.3.2,

$$\sum_{i \in Z_{2z}} a_{i2}^* - m_1^* A_o^* > 0,$$

if the number of producers in period 2 is large, and because $A_n^* < \infty$, given the requirements on T_{i1} and T_{i2} .

This inequality can be rewritten as:

$$\frac{[m_1^* A_o^* + m_{nz}^* A_n^*]}{\sum_{i \in Z_{2z}} a_{i2}^*} \leq 1 < \frac{[m_1^* A_o^* + [m_{nz}^* + 1] A_n^*]}{\sum_{i \in Z_{2z}} a_{i2}^*}.$$

Now, if $z = \infty$,

$$\frac{A_n^*}{\sum_{i \in Z_{2z}} a_{i2}^*} = 0, \text{ since } a_{i2}^* > 0, \forall i \in Z_{2z} \text{ and } A_n^* < \infty.$$

Therefore, if $z = \infty$,

$$\frac{[m_1^* A_o^* + m_{nz}^* A_n^*]}{\sum_{i \in Z_{2z}} a_{i2}^*} = 1 = \frac{[m_1^* A_o^* + [m_{nz}^* + 1] A_n^*]}{\sum_{i \in Z_{2z}} a_{i2}^*}, \text{ or:}$$

$$\sum_{i \in Z_{2z}} a_{i2}^* = [m_1^* A_o^* + m_{nz}^* A_n^*].$$

Hence, there exists a vector $((A_0^*)_{j \in M_1}, (A_n^*)_{j \in M_n})$, which implements the vector of individually optimal bids $(a_{i2}^*, A_n^*; \theta_{i1}, \theta_{i2})_{i \in Z_2}$, given that the number of producers in Z_2 is infinite, and if T_{i1} and T_{i2} satisfy the Unanimity Condition for the two-period model, as required. It can also be shown that, if the number of producers in Z_2 approaches infinity, the game coordinator can implement each producer's individually optimal bid in period 2 with a probability arbitrarily close to one if T_{i1} and T_{i2} satisfy the Unanimity Condition in period 2, using the same type of argument as in the proof of Proposition 1 in chapter 2.4. Hence, T_{i1} and T_{i2} satisfy the Implementability Condition for the two-period model if they satisfy the Unanimity Condition.

However, the actual number of new cooperatives built in period 2 may be small, even if the number of producers in period 2 is very large, if the number of cooperatives built in period 1 is large.

ONLY IF. Suppose that T_{i1} and T_{i2} do not satisfy the Unanimity Condition for period 2. In that case, the individually optimal bid of some producer in period 2 with type $(\theta_{L1}, \theta_{L2})$ in the subset Z_e , $(a_{L2}^*, A_{Ln}^*; \theta_{L1}, \theta_{L2})$ is such that: $a_{L2}^* \neq m_{Ln} A_{Ln}^*$ for any positive integer m_{Ln} and the individually optimal bid of another producer with type $(\theta_{H1}, \theta_{H2})$ in the subset Z_e , $(a_{H2}^*, A_{Hn}^*; \theta_{H1}, \theta_{H2})$ is such that: $a_{H2}^* \neq m_{Hn} A_{Hn}^*$ for any positive

integer m_{Hn} , and $A_{Ln}^* \neq A_{Hn}^*$. The individually optimal bid of each producer in period 2 is unique, given the assumptions on C_{i2} and the requirements on T_{i1} and T_{i2} . Hence, this inequality implies that $(\theta_{L1}, \theta_{L2}) \neq (\theta_{H1}, \theta_{H2})$.

Now, suppose that there are no producers in period 1 and that no cooperatives have been built in that period. In that case, all producers in period 2 are new producers who belong to the set Z_e . Suppose that the vector of types of all producers in the subset Z_e is $((\theta_{L1}, \theta_{L2}), (\theta_{H1}, \theta_{H2})_{z_e-1})$, where z_e is the number of producers in the set Z_e . In that case, the coordinator cannot satisfy condition (3) of the definition of bid implementation in period 2, which is stated in section 3.3.1, unless he builds a number m_{Ln}^* of new cooperatives with capacity A_{Ln}^* , such that:

$$a_{L2}^* > m_{Ln}^* A_{Ln}^* .$$

However, in that case, he violates condition (4) of the definition of bid implementation in period 2. Hence, the coordinator cannot implement the bid of the producer with type $(\theta_{L1}, \theta_{L2})$ with positive probability. This concludes part 1B of the proof of Proposition 3. It should be noted that the last "Only IF" part of this proof assumes that a producer's individually optimal output in period 1 is independent of his type in period 2 and vice versa. As is shown in part 2 of this proof, this is the case in an optimal ownership structure.

Part 2. Unanimity and Budget-Balance

In this part of the proof of Proposition 3, I establish that T_{i1} and T_{i2} satisfy the Unanimity Condition and the Budget-Balance Condition for the two-period model if and only if they have the form stated in Proposition 3.

IF If T_{i1} and T_{i2} have the form stated in Proposition 3, a producer earns in period 2:

$$V_{i2}(a_{i2}, A_{in}) = \frac{a_{i2}}{A_{in}} P_{in}(A_{in}; 0) - C_{i2}(a_{i2}; \theta_{i2}),$$

This income is independent of the producer's bid in period 1. Hence, the individually optimal bid of a producer in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i2})$, satisfies the following two first-order conditions:

$$(a_{i2}) \frac{1}{A_{in}} P_{in}(A_{in}; 0) - C_{i2}^a(a_{i2}; \theta_{i2}) = 0$$

$$(A_{in}) \frac{a_{in}}{A_{in}} [P_{in}^A(A_{in}; 0) - \frac{1}{A_{in}} P_{in}(A_{in}; 0)] = 0 .$$

Furthermore, if T_{i1} and T_{i2} have the form stated in Proposition 3, a producer in period 1 earns:

$$V_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i; \theta_{i1}) =$$

$$\frac{a_{i1}}{A_{i1}} [P_{i1}(A_{i1}, B_i) + P_{i0}(A_{i0}, B_i) - rB_i - A_{i0} \frac{P_n(A_n^*; 0)}{A_n^*}]$$

$$- C_{i1}(a_{i1}; \theta_{i1}),$$

where A_n^* satisfies the first-order condition (A_{in}) stated above. This income is independent of the producer's bid in period 2. Hence, the individually optimal bid of a producer in period 1, $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1})$, satisfies the following four first-order conditions:

$$(a_{i1}) \frac{1}{A_{i1}} [P_{i1}(A_{i1}, B_i) - rB_i + P_{io}(A_{io}, B_i) - A_{io} \frac{P_n(A_n^*; 0)}{A_n^*}] - C_{i1}^a(a_{i1}; \theta_{i1}) = 0,$$

$$(A_{i1}) \frac{a_{i1}}{A_{i1}} [P_{i1}^A - \frac{1}{A_{i1}} [P_{i1}(A_{i1}, B_i) - rB_i + P_{io}(A_{io}, B_i) - A_{io} \frac{P_n(A_n^*; 0)}{A_n^*}]] = 0$$

$$(A_{io}) \frac{a_{i1}}{A_{i1}} [P_{io}^A(A_{io}; B_i) - \frac{P_n(A_n^*; 0)}{A_n^*}] = 0$$

$$(B_i) \frac{a_{i1}}{A_{i1}} [P_{i1}^B(A_{i1}, B_i) + P_{io}^B(A_{io}, B_i) - r] = 0$$

The first-order conditions (A_{i1}), (A_{io}), (B_i) and (A_{in}) imply that T_{i1} and T_{i2} satisfy the Unanimity Condition of the two-period model.

Given that T_{i1} and T_{i2} satisfy the Unanimity Condition, the vectors of individually optimal bids of all producers in period 1 and 2 can be written as:

$$((a_{i1}^*; \theta_{i1}, \theta_{i2})_{i1 \in Z_1}, A_1^*, A_0^*, B^*) \text{ and}$$

$$((a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i2 \in Z_r}, (a_{i2}^*, \theta_{i1}, \theta_{i2})_{i2 \in Z_e}, A_n^*). \text{ As is}$$

explained in section 3.3.1, the game coordinator only builds new cooperatives in period 2 with a capacity equal to the bids of producers who expand their patronage between period 1 and 2. Hence, the Budget-Balance Condition of the two-period model can be written as follows.

The Budget-Balance Condition Given the Unanimity Condition

Given that T_{i1} and T_{i2} satisfy the Unanimity Condition, T_{i1} and T_{i2} satisfy the Budget-Balance Condition for the two-period model if and only if, for $\forall (\theta_{i1})_{i1 \in Z1}$ and $\forall (\theta_{i2})_{i2 \in Z2}$, the following condition is satisfied at the individually optimal bids of all producers in period 1 and 2,

$$\begin{aligned} & ((a_{i1}^*; \theta_{i1}, \theta_{i2})_{i1 \in Z1}, A_1^*, A_0^*, B^*) \text{ and} \\ & ((a_{i2}^*, A_n^*; \theta_{i1}, \theta_{i2})_{i2 \in Zr}, (a_{i2}^*, \theta_{i1}, \theta_{i2})_{i2 \in Ze}, A_n^*) \\ & \sum_{i1 \in Z1} T_{i1} + \sum_{i2 \in Z2} T_{i2} = \\ & \frac{\sum_{i1 \in Z1} a_{i1}^*}{A_1^*} [P_1(A_1^*, B^*) + P_0(A_0^*, B^*) - rB^* - A_0^* \frac{P_n(A_n^*; 0)}{A_n^*}] + \\ & \frac{\sum_{i2 \in Z2} a_{i2}^*}{A_n^*} P_n(A_n^*; 0), \end{aligned}$$

where A_n^* satisfies the first-order condition (A_n^*) .

Hence, T_{i1} and T_{i2} satisfy the Budget-Balance Condition of the two-period model if they have the form stated in Proposition 3 as well. T_{i1} and T_{i2} also satisfy the requirements stated in section 3.3.1, as the Hessian of V_{i2} and the Hessian of $(V_{i1} +$

V_{i2}) are negative definite, given the form of C_{i1} , C_{i2} , P_{j1} , P_{j0} and P_{jn} stated in section 3.3.1.

It should be pointed out that, if the profit-sharing rule in period 1 depended on each producer's individually optimal bid A_{in} as follows:

$$T_{i1} = \frac{a_{i1}}{A_{i1}} [P_{i1}(A_{i1}, B_i) + P_{i0}(A_{i0}, B_i) - rB_i - A_{i0} \frac{P_{in}(A_{in}; 0)}{A_{in}}],$$

the producers in period 2 in the set Z_r , who reduce their patronage between period 1 and 2, would prefer any capacity of a new cooperative to A_n^* which satisfies first-order condition (A_{in}) above, while all producers in the set Z_e , who expand their patronage between period 1 and 2 would prefer A_n^* to any other capacity of a new cooperative in period 2.

In that case, if $P_{jn}(A_{jn}; 0) \geq 0$, $\forall A_{jn}$, all producers in the set Z_r would bid $A_{in}^* = 0$. Given the alternative profit-sharing rule stated above, these producers would then be paid:

$$T_{i1} = \frac{a_{i1}}{A_{i1}} [P_{i1}(A_{i1}, B_i) + P_{i0}(A_{i0}, B_i) - rB_i].$$

Clearly, this would violate the Budget-Balance Condition.

ONLY IF Below, I derive the profit-sharing rules T_{i1} and T_{i2} stated in Proposition 3 directly from the Unanimity Condition and the Budget-Balance Condition for the two-period model, given the requirements on T_{i1} and T_{i2} stated in section 3.3.1. This proof is very similar to that of Proposition 2 in chapter 2. To derive T_{i1} and T_{i2} , I first state the following facts.

FACT 5. For any T_{i1} and T_{i2} , the derivatives of a_{i1} and a_{i2} with respect to θ_{i1} and θ_{i2} are as follows, for $\forall i \in Z1$ and $\forall i \in Z2$, at the individually optimal bids of all producers in period 1 and period 2, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$, and $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z2}$:

$$\frac{\delta a_{i1}}{\delta \theta_{i1}} > 0, \quad \frac{\delta a_{i2}}{\delta \theta_{i2}} > 0,$$

while the signs of:

$$\frac{\delta a_{i1}}{\delta \theta_{i2}} \text{ and of } \frac{\delta a_{i2}}{\delta \theta_{i1}}$$

are the same. This sign is indeterminate.

As in the proof of Proposition 2, Fact 5 can be established by differentiating the first-order conditions which characterize a producer's individually optimal bid with respect to $\theta_{i1}, \theta_{i2}, a_{i1}, a_{i2}, A_{i1}, A_{i0}, B_i$ and A_{in} . Given Fact 5, a_{i1}^* and a_{i2}^* can be written as functions of $(\theta_{i1}, \theta_{i2})$, which I denote as $a_{i1}^*(\theta_{i1}, \theta_{i2})$ and $a_{i2}^*(\theta_{i1}, \theta_{i2})$, respectively.

FACT 6. If T_{i1} and T_{i2} satisfy the Unanimity Condition for the two-period model, the derivatives of A_{i1}, A_{i0}, B_i and A_{in} with respect to θ_{i1} and θ_{i2} are as follows, $\forall i \in Z1$ and $\forall i \in Z2$ at the individually optimal bids of all producers in period 1 and period 2,

$(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})_{i \in Z1}$, and $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Z2}$:

$$\frac{\delta A_{i1}}{\delta \theta_{i1}} = 0, \quad \frac{\delta A_{i1}}{\delta \theta_{i2}} = 0, \quad \frac{\delta A_{i0}}{\delta \theta_{i1}} = 0, \quad \frac{\delta A_{i0}}{\delta \theta_{i2}} = 0,$$

$$\frac{\delta A_{in}}{\delta \theta_{i1}} = 0, \quad \frac{\delta A_{in}}{\delta \theta_{i2}} = 0, \quad \frac{\delta B_i}{\delta \theta_{i1}} = 0, \quad \frac{\delta B_i}{\delta \theta_{i2}} = 0.$$

This fact is implied by the definition of the Unanimity Condition. Furthermore, Fact 4 implies that the derivatives of $a_{i1}, a_{i2}, A_{i1}, A_{i0}, B_i, A_{in}$ with respect to θ_{j1} and θ_{j2} equal zero.

Given these facts, the proof proceeds as follows. First, given that T_{i1} and T_{i2} satisfy the Unanimity Condition for the two-period model, the Budget-Balance condition can be restated in the form given above. Differentiating the left-hand side and the right-hand side of this Budget-Balance Condition with respect to θ_{i1} , given θ_{i2} , yields equality 1A, while differentiating the left-hand side and the right-hand side of this Budget-Balance Condition with respect to θ_{i2} , given θ_{i1} , yields equality 1B:

$$(1A) [T_{i1}^{a1} + T_{i2}^{a1}] \frac{\delta a_{i1}}{\delta \theta_{i1}} + T_{i2}^{a2} \frac{\delta a_{i2}}{\delta \theta_{i1}} = \frac{P_n(A_n^*;0)}{A_n^*} \frac{\delta a_{i2}}{\delta \theta_{i1}} +$$

$$\frac{1}{A_1^*} [P_1(A_1^*, B^*) + P_0(A_0^*, B^*) - rB^* - A_0^* \frac{P_n(A_n^*;0)}{A_n^*}] \frac{\delta a_{i1}}{\delta \theta_{i1}} .$$

$$(1B) [T_{i1}^{a1} + T_{i2}^{a1}] \frac{\delta a_{i1}}{\delta \theta_{i2}} + T_{i2}^{a2} \frac{\delta a_{i2}}{\delta \theta_{i2}} = \frac{P_n(A_n^*;0)}{A_n^*} \frac{\delta a_{i2}}{\delta \theta_{i2}} +$$

$$\frac{1}{A_1^*} [P_1(A_1^*, B^*) + P_0(A_0^*, B^*) - rB^* - A_0^* \frac{P_n(A_n^*;0)}{A_n^*}] \frac{\delta a_{i1}}{\delta \theta_{i2}} .$$

Secondly, integrating (1A) over θ_{i1} , given θ_{i2} , yields equality (2A) and integrating (1B) over θ_{i2} , given θ_{i1} , yields equality (2B):

$$(2A) T_{i1} + T_{i2} = Z_{i1} + F(a_{i2}^*(\theta_{i1}; \theta_{i2})) \left[\frac{P_n(A_n^*;0)}{A_n^*} \right] +$$

$$\frac{a_{i1}^*}{A_1^*} [P_1(A_1^*, B^*) + P_0(A_0^*, B^*) - rB^* - A_0^* \frac{P_n(A_n^*;0)}{A_n^*}] .$$

$$(2B) T_{i1} + T_{i2} = Z_{i2} + \frac{a_{i2}^*}{A_n^*} P_n(A_n^*;0) +$$

$$F(a_{i1}^*(\theta_{i2}; \theta_{i1})) \left[\frac{1}{A_1^*} [P_1(A_1^*, B^*) + P_0(A_0^*, B^*) - rB^* - A_0^* \frac{P_n(A_n^*;0)}{A_n^*}] \right]$$

where $F(a_{i2}^*(\theta_{i1}; \theta_{i2}))$ equals:

$$\int_{\theta_{i1}} \frac{\delta a_{i2}}{\delta \theta_{i1}} d\theta_{i1}, \text{ where } \theta_{i1} \text{ solves: } \text{MAX}_{\theta_{i1}} \theta_{i1}, \text{ s.t. } a_{i1}^*(\theta_{i1}; \theta_{i2}) = 0$$

and where $F(a_{i1}^*(\theta_{i2}; \theta_{i1}))$ equals:

$$\int_{\theta_{i2}} \frac{\delta a_{i1}}{\delta \theta_{i2}} d\theta_{i2}, \text{ where } \theta_{i2} \text{ solves: } \text{MAX}_{\theta_{i2}} \theta_{i2}, \text{ s.t. } a_{i2}^*(\theta_{i2}; \theta_{i1}) = 0$$

Combining equalities (2A) and (2B) yields, at

$(a_{i1}^*(\theta_{i2}, \theta_{i1}), a_{i1}^*(\theta_{i2}, \theta_{i1}))$:

$$T_{i1} + T_{i2} = Z_i + \frac{a_{i2}^*}{A_n^*} P_n(A_n^*; 0) + \frac{a_{i1}^*}{A_1^*} [P_1(A_1^*, B^*) + F_0(A_0^*, B^*) - rB^* - A_0^* \frac{P_n(A_n^*; 0)}{A_n^*}] .$$

Requirements (3), (4) and (5) on T_{i1} and T_{i2} stated in section 3.3.1 then imply that T_{i1} and T_{i2} must have the form stated in Proposition 3 at each producer's individually optimal bid in period 1 and period 2. This concludes part 2 of the proof of Proposition 3.

Part 3. Optimality of T_{i1} and T_{i2}

In this part, I prove that T_{i1} and T_{i2} satisfy the Optimality Condition, given that they satisfy the Unanimity Condition, if they have the form stated in Proposition 3. The Optimality Condition can be rewritten as follows.

The Optimality Condition Given the Unanimity Condition

Given that T_{i1} and T_{i2} satisfy the Unanimity Condition, T_{i1} and T_{i2} satisfy the Optimality Condition for the two-period model if and only if, for $\forall(\theta_{i1})_{i \in Z1}$ and $\forall(\theta_{i2})_{i \in Z2}$, the individually optimal bids of all producers in period 1 and 2,

$((a_{i1}^*; \theta_{i1}, \theta_{i2})_{i \in Z1}, A_1^*, A_0^*, B^*)$ and

$((a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})_{i \in Zr}, (a_{i2}^*; \theta_{i1}, \theta_{i2})_{i \in Ze}, A_n^*)$ solve:

$$\begin{aligned} & \text{MAX} \\ & ((a_{i1})_{i \in Z1}, (a_{i2})_{i \in Z2}, A_1, A_0, B, A_n) \\ & \frac{\sum_{i \in Z1} a_{i1}}{A_1} [P_1(A_1, B) + P_0(A_0, B) - rB - A_0 \frac{P_n(A_n; 0)}{A_n}] + \\ & \frac{\sum_{i \in Z2} a_{i2}}{A_n} P_n(A_n; 0) - \sum_{i \in Z1} C_{i1}(a_{i1}; \theta_{i1}) - \sum_{i \in Z2} C_{i2}(a_{i2}; \theta_{i2}). \end{aligned}$$

Given the assumptions on $P_{j1}, P_{j0}, P_{jn}, C_{i1}$ and C_{i2} , the solution to this problem is unique. This solution is characterized by the first-order conditions stated in Part 2 of the proof of Proposition 3, if:

$$\frac{\sum_{i \in Z1} a_{i1}^*}{A_1^*} \geq \frac{\sum_{i \in Z2} a_{i2}^*}{A_0^*},$$

which is implied by the assumption that:

$$\sum_{i \in Z2} a_{i2}^* \geq \sum_{j \in M1} A_{j0}^*,$$

which was stated in section 3.3.1. Therefore, T_{i1} and T_{i2} satisfy the Optimality Condition if they have the form stated in Proposition 3. This concludes the proof of Proposition 3.

3.3.4 A Test on the Cooperative Horizon Problem

If T_{i1} and T_{i2} have the form stated in Proposition 3, the Strong Nash Equilibrium in Dominant Strategies formed by the producers' individually optimal bids in period 1 and period 2 has the following characteristics. First, each producer in period 1 and 2 chooses an individual output level which maximizes his income, given the profit per unit of patronage he earns if he supplies a cooperative.

Secondly, the members of an old cooperative in period 1 unanimously choose a capacity in period 1, A_1^* , which maximizes the cooperative's profits in periods 1 and 2 per unit of patronage in period 1. In addition, they choose a capacity of their old cooperative in period 2, A_0^* , which maximizes the profit of an old cooperative in period 2 which is due to its investment in period 1, given the average profit its suppliers in period 2 can earn if they supply a new cooperative instead. Finally, they unanimously choose an investment in their cooperative, B^* , which maximizes the cooperative's profits in periods 1 and 2 minus the cost of this investment. Thirdly, the producers in period 2 choose a capacity of a new cooperative, A_n^* , which maximizes its profit per unit of patronage. As was established in part 3 of the proof of Proposition 3, this ownership structure maximizes the joint income of all producers in periods 1 and 2. I conclude that such an ownership structure resolves the Horizon Problem described in section 3.2.1.

The conditions which characterize the capacities of an old and a new cooperative and the investment in an old cooperative if an ownership structure has the form stated in Proposition 3 can be used to specify a test which can be used to determine whether an ownership structure resolves the Horizon Problem. This test is used in the next two sections to compare alternative ownership structures.

Definition of a Test on the Cooperative Horizon Problem

An ownership structure (T_{i1}, T_{i2}) resolves the Horizon Problem if and only if, $\forall (\theta_{i1})_{i \in Z1}$ and $\forall (\theta_{i2})_{i \in Z2}$, the individually optimal bids of each producer in period 1, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})$, and each producer in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$, satisfy the following four conditions:

$$(A) P_{i1}^A - \frac{1}{A_{i1}} [P_{i1} - rB_i + P_{i0} - \frac{A_{i0}}{A_{in}} P_{in}] = 0 ,$$

$$(B) P_{i0}^A - \frac{P_{in}}{A_{in}} = 0 ,$$

$$(C) P_{i1}^B + P_{i0}^B - r = 0 ,$$

$$(D) P_{in}^A - \frac{P_{in}}{A_{in}} = 0 .$$

These conditions are implied by FOC's (A_{i1}) , (A_{i0}) , (B_i) and (A_{in}) , which are stated in Part 2 of the proof of Proposition 3.

3.4 Comparison of Alternative Ownership Structures

This section compares three cooperative ownership structures, to determine which of these resolve the Horizon Problem, using the test specified at the end of section 3.3.3. These ownership structures are:

Revolving Equity In this structure, the members of a cooperative share the cost of a cooperative's equity in each period in proportion to their share of its patronage in that period.

Fixed Patronage Shares In this structure, each member's share of the total supply to a cooperative in period 2 must equal his share of its supply in period 1.

Patronage Rights In this structure, members of a cooperative in period 1 can sell the right to supply their cooperative in period 2 to producers in period 2.

Section 3.4.1 shows that an ownership structure with revolving equity does not resolve the Horizon Problem. Section 3.4.2 and 3.4.3 show that an ownership structure with fixed patronage shares and a structure with patronage rights do resolve the Horizon Problem. These results confirm my claims in sections 3.2.1 and 3.2.2.

These three ownership structures are assumed to be embodied in the statutes of the cooperative to which they apply. I assume that, in each of these three ownership structures, the members of a cooperative share its net profit in proportion to patronage in each period. In addition, I assume that in each of these three ownership structures, the cooperative's members have adopted the following voting procedure, which is the same as the bidding procedure described in section 3.3.1. All producers who want to supply a cooperative in period 1 submit votes stating their individually optimal output, the capacity of the cooperative they want to supply in period 1, the capacity of that same cooperative in period 2 and the investment in that cooperative in period 1. In terms of the two-period cooperative decision model, this vote is denoted by $(a_{i1}, A_{i1}, A_{i0}, B_i)$. All producers who want to supply a cooperative in period 2 submit votes stating their individual output in period 2 as well as the capacity of a new cooperative they may supply in that period. This vote is denoted by (a_{i2}, A_{in}) .

3.4.1. Revolving Equity

This section first shows that, if the members of a cooperative adopt an ownership structure with revolving equity and profit-sharing in proportion to patronage, they share the total cost of an investment in their cooperative in the period that the cost of this investment is incurred in proportion to their share of its patronage in this period. This method of profit-

sharing resolves the Horizon Problem if an investment pays off in the same period in which its cost is incurred, as was shown in chapter 2.

This section then demonstrates that this method of profit-sharing does not resolve the Horizon Problem if an investment pays off in more than one period and if the members of the cooperative change their share of the cooperative's patronage between the periods in which that investment pays off. This confirms my claim in section 3.2.1.

Revolving Equity and Cost-Sharing

The total cost of a cooperative's investment to its members consists of two parts, which I call its cash-flow cost and its equity cost. The cash-flow cost of an investment is the cost of depreciation plus the interest cost on borrowed capital used to finance the investment. This part is paid out of the cooperative's profit. Hence, a member's share of the cash-flow cost of an investment in each period equals his share of the cooperative's profit in that period. The equity cost of an investment is the cost of financing the cooperative's investment with the equity on its balance sheet. Each member's share of this cost equals his share of the book value of the cooperative's equity.

Hence, to ensure that the members of a cooperative share the total cost of an investment in proportion to their patronage

in the period when it is incurred, they must ensure that each member's share of its profit and his share of the book value of its equity equals his share of its patronage in that period. If a cooperative shares its profit in each period in proportion to patronage, a member's share of the book value of the cooperative's equity equals his share of the cooperative's patronage in previous periods, when the cooperative retained some of its profit as equity. Hence, if a member changes his share of the cooperative's patronage over time, his cumulative share of the book value of its equity does not equal his share of its patronage in each period.

To ensure that a member's share of the book value of the cooperative's equity in each period equals his share of its patronage in that period, a cooperative can adopt an ownership structure with revolving equity. In such a structure, the cooperative pays a member's contribution to its equity in a previous period back after some time. If the cooperative repays its members for their equity contribution at the end of each period in which they made that contribution, a member's share of the book value of the cooperative's equity in each period equals his share of its patronage in that period.

Most cooperatives which adopt revolving equity do not pay back their members' contributions to its equity at the end of each period, because such rapid revolvment would reduce their ability to finance its growth by retaining equity. [Caves and

Petersen, 1986]. In such cooperatives, the Horizon Problem arises even if its investment pays off in the period that its cost is incurred, unless each member's share of the cooperative's patronage does not change over time.

However, it is possible to ensure that a member's share of the cooperative's equity equals his share of its patronage in each period without impeding its growth, by adopting a variation on revolving equity, called the Base Capital Plan. This plan is described in the appendix of chapter 4 and in USDA [1982]. In this plan, a member who increases his share of the cooperative's patronage in some period is required to make an additional contribution to the cooperative's equity in that period. This contribution is used to pay off members who have reduced their share of its patronage.

Revolving Equity and the Horizon Problem

However, even if a cooperative which has an ownership structure with revolving equity adopts a Base Capital Plan, it cannot resolve the Horizon Problem for an investment which pays off over more than one period and if its members' share of its patronage changes between those periods. This is demonstrated below, using the two-period decision model.

In terms of the two-period cooperative decision model, a cooperative ownership structure with revolving equity and profit-sharing in proportion to patronage can be described as

follows. A cooperative's investment in period 1 is B_j . A part of the cost of this investment, αB_j , is incurred in period 1 and the rest, $(1-\alpha)rB_j$, is incurred in period 2. I assume that α is determined by some exogenous accounting rules and tax considerations.

I also assume that the incumbent members of an old cooperative can choose whether to supply an old or a new cooperative in period 2. This assumption is necessary, because, in this ownership structure, the incumbent producers in period 2 are not always indifferent between supplying an old or a new cooperative, as is demonstrated below. To allow this choice, I assume that the optimal aggregate capacity of the old cooperatives in period 2 is large enough to accommodate the aggregate optimal output of all incumbent producers in period 2, if they choose to supply an old cooperative. In addition, the incumbent producers may admit some new producers to an old cooperative in period 2 to fully use its capacity, free of charge.

It can be shown that the Horizon Problem in an ownership structure with revolving equity is resolved if the members of an old cooperative in period 1 can charge producers in period 2 a fee for the right to supply their cooperative and if the members of that cooperative in period 1 share this fee in proportion to their patronage in period 1. However, such an

ownership structure is essentially an ownership structure with patronage rights, which is examined in section 3.4.3.

If the cooperative adopts an ownership structure with revolving equity and profit-sharing in proportion to patronage, a producer in period 1 earns:

$$V_{i1}(a_{i1}, A_{i1}, B_i; \theta_{i1}) = \frac{a_{i1}}{A_{i1}} [P_{i1} - \alpha r B_i] - C_{i1} .$$

If that producer supplies an old cooperative in period 2, he earns:

$$V_{i0}(a_{i0}, A_{i0}, B_i; \theta_{i2}) = \frac{a_{i0}}{A_{i0}} [P_{i0} - (1-\alpha)r B_i] - C_{i2} ,$$

where (a_{i0}) denotes his output if he supplies an old cooperative. If that producer supplies a new cooperative in period 2 instead, he earns:

$$V_{in}(a_{in}, A_{in}; \theta_{i2}) = \frac{a_{in}}{A_{in}} P_{in} - C_{i2} ,$$

where a_{in} denotes his output if he supplies a new cooperative.

In that case, the individually optimal votes of an incumbent producer in period 1, $(a_{i1}^*, A_{i1}^*, A_{i0}^*, B_i^*; \theta_{i1}, \theta_{i2})$, and in period 2, $(a_{i0}^*, a_{in}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$, solve the following maximization problem:

$$\text{MAX}_{(a_{i1}, a_{i0}, a_{in}, A_{i1}, A_{i0}, A_{in}, B_i)} V_{i1} + V_{i2} ,$$

where V_{i2} equals $\max(V_{i0}, V_{in})$.

These votes are characterized by the first-order conditions to this maximization problem:

$$(a_{i1}) \frac{1}{A_{i1}} [P_{i1} - \alpha r B_i] - C_{i1}^a = 0,$$

$$(a_{i0}) \frac{1}{A_{i0}} [P_{i0} - (1-\alpha)r B_i] - C_{i2}^a = 0,$$

$$(a_{in}) \frac{P_{in}}{A_{in}} - C_{i2}^a = 0,$$

$$(A_{i1}) \frac{a_{i1}}{A_{i1}} [P_{i1}^A - \frac{1}{A_{i1}} [P_{i1} - \alpha r B_i]] = 0,$$

$$(A_{i0}) \frac{a_{i0}}{A_{i0}} [P_{i0}^A - \frac{1}{A_{i0}} [P_{i0} - (1-\alpha)r B_i]] = 0, \text{ if } a_{i0}^* \geq 0,$$

$$(A_{in}) \frac{a_{in}}{A_{in}} [P_{in}^A - \frac{P_{in}}{A_{in}}] = 0, \text{ if } a_{in}^* > 0,$$

$$(B_i) \frac{a_{i1}}{A_{i1}} [P_{i1}^B - \alpha r] + \frac{a_{i0}}{A_{i0}} [P_{i0}^B - (1-\alpha)r] = 0,$$

where $a_{i0}^* \geq 0$ if $V_{i0}(a_{i0}^*, A_{i0}^*; \theta_{i2}) \geq 0$ and if:

$$\frac{1}{A_{i0}^*} [P_{i0}(A_{i0}^*; B_i^*) - (1-\alpha)r B_i^*] \geq \frac{P_{in}(A_{in}^*; 0)}{A_{in}^*}.$$

A new producer in period 2 earns $V_{i0}(a_{i0}; \theta_{i2})$ if he supplies an old cooperative with a given capacity and investment, and $V_{in}(a_{in}, A_{in}; \theta_{i2})$ if he supplies a new cooperative. Hence, the individually optimal vote of a new producer in period 2, $(a_{i0}^*, a_{in}^*, A_{in}^*; \theta_{i2})$, satisfies FOC's (a_{i0}) , (a_{in}) and (A_{in}) .

In this ownership structure, FOC's (A_{i1}^*) , (A_{i0}^*) , (A_{in}^*) and (B_i) do not satisfy the four conditions of the test on the cooperative Horizon Problem, unless both of the following two conditions are satisfied at the individually optimal votes of all incumbent producers in period 1 and 2:

1. One of the following three conditions is satisfied at the individually optimal votes in period 1 and period 2 of each incumbent producer.

$$(1a) \frac{a_{i1}^*}{A_{i1}^*} = \frac{a_{i0}^*}{A_{i0}^*}, \text{ or}$$

$$(1b) P_{i1}^B(A_{i1}^*, B_i^*) = 0 \text{ and } \alpha = 0, \text{ or}$$

$$(1c) P_{i0}^B(A_{i0}^*; B_i^*) = 0 \text{ and } \alpha = 1.$$

2. The following condition is satisfied at the individually optimal vote of each incumbent producer.

$$\frac{1}{A_{i0}^*} [P_{i0}^B(A_{i0}^*; B_i^*) - (1-\alpha)rB_i^*] = \frac{P_{in}^B(A_{in}^*; 0)}{A_{in}^*}.$$

Condition 1 ensures that the first-order condition (B_i) satisfies condition (C) of the test on the cooperative Horizon Problem, if condition 2 is satisfied. Condition (1a) does not hold unless each member's share of the cooperative's patronage is constant in the periods in which this investment pays off. This condition is generally not satisfied if a producer's type

changes between period 1 and 2, for example because he retires. Conditions (1b) and (1c) hold only if a cooperative's investment pays off only in the period in which its cost is incurred. Hence, condition 1 implies that a cooperative ownership structure with revolving equity does not resolve the Horizon Problem for an investment which pays off in more than one period, if the share of the cooperative's patronage of some of its members changes between those periods.

More specifically, comparison of $FQC(B_i)$ with condition (C) of the test on the Horizon Problem suggests the following. Under an ownership structure with revolving equity, a member of a cooperative in period 1 who plans to reduce his share of its patronage between period 1 and period 2 will choose to invest less in an asset which is written off in period 1 and which pays off in period 2 ($\alpha = 1$ and $P_{i0}^B > 0$) than he would in an ownership structure which resolves the Horizon Problem. Hence, if such members are in the majority in a cooperative in period 1, they will underinvest in such assets. Conversely, a member who plans to reduce his patronage of the cooperative between period 1 and period 2 will prefer to invest more in an asset which is written off in period 2 and which pays off in period 1 ($\alpha = 0$ and $P_{i1}^B > 0$) than he would in an ownership structure which resolves the Horizon Problem. Hence, if such members are in the majority in a cooperative in period 1, they will overinvest in such assets.

Condition 2 ensures that FOC's (A_{i1}) and (A_{i0}) satisfy conditions (A) and (B) of the test on the Horizon Problem, if condition 1 is satisfied. The left-hand side of condition 2 is the profit per unit of patronage of an old cooperative in period 2, which is maximized at A_{i0}^* , given B_i^* . The right-hand side is the profit per unit of patronage of a new cooperative in period 2, which is maximized at A_{in}^* , given that its investment in period 1 equals zero. If the right-hand side of this equation is less than the left hand side, no incumbent producer will supply an old cooperative in period 2. If the left-hand side is less than the right-hand side, all incumbent producers will choose to supply only old cooperatives in period 2. If condition (2) is satisfied, all producers in period 2 are indifferent between supplying an old or a new cooperative, as is required in an ownership structure which resolves the Horizon Problem.

If an investment is written off in period 1 and if it does not increase the profit of an old cooperative in period 2 ($\alpha = 1$ and $P_{i0}(A_{i0}^*; B_i^*) = P_{i0}(A_{i0}^*; 0)$), this condition is satisfied. However, if an investment is written off in period 1 and if it increases the profit of an old cooperative in period 2, this condition is not satisfied, unless B_i^* equals zero. This implies that an ownership structure with revolving equity does not resolve the Horizon Problem for expensed investments which pay off in more than one period, even if each incumbent producer's share of the patronage of an old cooperative in

period 2 equals his share of its patronage in period 1. The reason for this is that, in case of expensed investments, the incumbent producers will choose a capacity of an old cooperative in period 2 which maximizes its profit per unit of patronage in that period. This is implied by FOC (A_{i_0}) given above. In an ownership structure which resolves the Horizon Problem on the other hand, the producers in period 2 choose a capacity of an old cooperative which maximizes the profit of an old cooperative in period 2 which is due to its investment in period 1. This is implied by condition (B) of the test on the cooperative Horizon Problem.

3.4.2. Fixed Patronage Shares

In this ownership structure, each member's share of the patronage of an old cooperative in period 2 must equal his share of its patronage in period 1. This implies that all old cooperatives in period 2 are supplied only by incumbent producers. This section shows that this ownership structure resolves the Horizon Problem, assuming that a member of an old cooperative in period 2 can sell some of his output to a new cooperative in period 2 and that he can buy some additional product from other producers, to meet his obligation to supply his old cooperative.

In terms of the two-period cooperative decision model, an incumbent member of an old cooperative can supply a_{i1} to his cooperative in period 1, and:

$$a_{i0} = a_{i1} \frac{A_{i0}}{A_{i1}} \text{ to his cooperative in period 2.}$$

In addition, an incumbent member of an old cooperative in period 2 can supply:

$$a_{in} = a_{i2} - a_{i1} \frac{A_{i0}}{A_{i1}} \text{ to a new cooperative,}$$

where a_{in} may be negative, as long as a_{i1} and a_{i2} are positive. If a_{in} is positive, this producer supplies a_{in} to a new cooperative. If it is negative, this producer buys a_{in} to meet his fixed obligations to supply his old cooperative.

If all cooperatives adopt profit-sharing in proportion to patronage in periods 1 and 2, an incumbent member earns:

$$a_{in} \frac{P_{in}}{A_{in}}, \text{ if he supplies } a_{in} \text{ to a new cooperative.}$$

I assume that, if an incumbent producer wants to buy a_{in} from another producer to meet his obligations to supply his old cooperative, he must pay:

$$a_{in} \frac{P_n(A_n^*;0)}{A_n^*},$$

where A_n^* is the unanimous vote on the capacity of a new cooperative in period 2 of all producers who expand their patronage between period 1 and 2.

In that case, a producer in period 1 earns:

$$V_{i1}(a_{i1}, A_{i1}, B_i; \theta_{i1}) = \frac{a_{i1}}{A_{i1}} [P_{i1} - rB_i] - C_{i1},$$

In period 2, that producer earns:

$$V_{i2}(a_{i2}, A_{i0}, A_{in}; \theta_{i2}) = \frac{a_{i1}}{A_{i1}} P_{i0} + [a_{i2} - a_{i1} \frac{A_{i0}}{A_{i1}}] \frac{P_{in}}{A_{in}} - C_{i2}.$$

$$\text{if } a_{i2} - a_{i1} \frac{A_{i0}}{A_{i1}} > 0,$$

and he earns:

$$V_{i2}(a_{i2}, A_{i0}; \theta_{i2}) = \frac{a_{i1}}{A_{i1}} P_{i0} + [a_{i2} - a_{i1} \frac{A_{i0}}{A_{i1}}] \frac{P_n(A_n^*;0)}{A_n^*} - C_{i2}.$$

$$\text{if } a_{i2} - a_{i1} \frac{A_{i0}}{A_{i1}} \leq 0.$$

A new producer in period 2 earns:

$$V_{i2}(a_{i2}, A_{in}; \theta_{i2}) = \frac{a_{i2}}{A_{in}} P_{in} - C_{i2} .$$

In this case, the optimal votes of an incumbent producer in period 1, $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1}, \theta_{i2})$, and in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$, solve the following maximization problem:

$$\text{MAX}_{(a_{i1}, a_{i2}, A_{i1}, A_{io}, A_{in}, B_i)} V_{i1} + V_{i2} .$$

These votes are characterized by the first-order conditions to this maximization problem:

$$(a_{i1}) \frac{1}{A_{i1}} [P_{i1} - rB_i + P_{io} - A_{io} \frac{P_{in}}{A_{in}}] - C_{i1}^a = 0 ,$$

$$(a_{i2}) \frac{P_{in}}{A_{in}} - C_{i2}^a = 0 ,$$

$$(A_{i1}) \frac{a_{i1}}{A_{i1}} [P_{i1}^A - \frac{1}{A_{i1}} [P_{i1} - rB_i + P_{io} - A_{io} \frac{P_{in}}{A_{in}}]] = 0 ,$$

$$(A_{io}) \frac{a_{i1}}{A_{i1}} [P_{io}^A - \frac{P_{in}}{A_{in}}] = 0 ,$$

$$(A_{in}) [\frac{a_{i2}}{A_{in}} - \frac{a_{i1}}{A_{i1}} \frac{A_{io}}{A_{in}}] [P_{in}^A - \frac{P_{in}}{A_{in}}] = 0 , \text{ if } a_{i2}^* - a_{i1}^* \frac{A_{io}^*}{A_{i1}^*} > 0 ,$$

$$(B_i) \frac{a_{i1}}{A_{i1}} [P_{i1}^B + P_{io}^B - r] = 0 .$$

In addition, the individually optimal vote of a new producer in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i2})$, maximizes his income in period 2, V_{i2} . This vote is characterized by FOC's (a_{i2}) and (A_{in}) given above, where a_{i1}^* equals zero for a new producer in period 2.

If a part (α) of the cost of an investment in an old cooperative is incurred in period 1 and a part $(1-\alpha)$ in period 2, the first-order conditions to the maximization problem of an incumbent producer are identical to those stated above.

FOC's $(A_{i1}), (A_{i0}), (A_{in})$ and (B_i) imply that the individually optimal votes of an incumbent producer in periods 1 and 2 and a new producer in period 2 satisfy the four conditions of the test on the Horizon Problem specified in section 3.3.3, no matter when the cost of this investment is incurred. Hence, an ownership structure with fixed patronage shares resolves the Horizon Problem. The optimal capacities of old and new cooperatives and the optimal investment in old cooperatives in such an ownership structure are equal to those in an optimal ownership structure, described in section 3.3.3.

However, such an ownership structure has two disadvantages, compared to a structure with patronage rights. First, if a cooperative adopts an ownership structure with fixed patronage shares instead of with patronage rights, it does not create a market for the right to supply it. If such a market exists, the market price for such a right provides an objective measure of the value of supplying that cooperative instead of another firm. Therefore, an ownership structure with fixed patronage shares has none of the advantages associated with creating such a market, which are described in section 3.2.2.

Secondly, suppose that a member of an old cooperative wants to reduce his own share of the total supply to his old cooperative in period 2. In an ownership structure with patronage rights, this requires only one transaction: the sale of patronage rights by the incumbent member to another supplier. In the case of an ownership structure with fixed shares, it requires that this member continues to buy product from other suppliers forever, to meet his supply obligations to his old cooperative. Assuming that the transaction cost of this stream of future product purchases is higher than the transaction cost of a one-time sale of patronage rights, an ownership structure with patronage rights is more efficient than one with fixed patronage shares.

These arguments are illustrated by the case study on the Cooperative Company Friesland (CCF) in chapter 5. CCF had adopted an ownership structure with fixed patronage shares, to protect each member's share of the profit generated by its past investments in developing its overseas markets for condensed milk. [ch 5: appendix] The case suggests that this ownership structure had the two disadvantages mentioned above. First, the fixed supply obligations in this ownership structure caused a suboptimal allocation of milk between the member cooperatives of CCF. These cooperatives produced a range of other dairy products themselves. However, because each member's obligation to supply CCF was fixed, a member

cooperative which had more profitable opportunities to produce dairy products itself could not reduce its share of the milk supply to CCF in favor of a member which had less profitable uses for its milk. [ch 5: p7,exh 21]

Secondly, this structure caused a suboptimal allocation of milk between CCF itself and its members, because this structure did not provide a mechanism to measure the performance of CCF relative to its members, given its past investments. As a result, it was difficult for CCF's members to determine how much milk they should supply to CCF and how much they should use in their own operations. Instead, they supplied as much milk to CCF as its management requested, usually around 15% of their total milk supply, even in periods when CCF's net profit per unit of milk was much lower than the profit its member-cooperatives could earn by processing milk themselves. [Ch 5: exh 19,20,21]

3.4.3. Patronage Rights

An ownership structure with patronage rights is described in section 3.2.2. In such an ownership structure, the members of a cooperative in period 1 can sell the right to use their cooperative to producers in period 2. In terms of the two-period cooperative decision model, a member of a cooperative in period 1 owns a share of these rights, equal to:

$$\frac{a_{i1}}{A_{i1}} A_{i0} ,$$

where A_{i1} is the capacity of the cooperative supplied by that member in period 1 and A_{i0} is the capacity of that cooperative in period 2. At the beginning of period 2, the members of an old cooperative in period 1 sell their patronage rights to the producers in period 2 who want to supply their cooperative. The buyers of these rights can be new producers or incumbents.

If all cooperatives adopt profit-sharing in proportion to patronage, a supplier of a new cooperative with capacity A_n^* will pay no more for a patronage right of an old cooperative with a capacity A_{j0} and an investment level B_j than:

$$\frac{P_{j0}(A_{j0}; B_j)}{A_{j0}} - \frac{P_n(A_n^*; 0)}{A_n^*} .$$

Given this competitive price of a patronage right, a producer in period 1 earns $V_{i1}(a_{i1}, A_{i1}, A_{i0}, B_i; \theta_{i1})$ which equals:

$$V_{i1} = \frac{a_{i1}}{A_{i1}} [P_{i1} + P_{i0} - rB_i - \frac{A_{i0}}{A_n^*} P_n(A_n^*; 0)] - C_{i1} .$$

In addition, all producers in period 2 earn:

$$V_{i2}(a_{i2}, A_{in}; \theta_{i2}) = \frac{a_{i2}}{A_{in}} P_{in} - C_{i2} ,$$

In that case, the individually optimal votes of an incumbent producer in period 1, $(a_{i1}^*, A_{i1}^*, A_{io}^*, B_i^*; \theta_{i1}, \theta_{i2})$, and in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i1}, \theta_{i2})$, solve the following maximization problem:

$$\text{MAX}_{(a_{i1}, a_{i2}, A_{i1}, A_{io}, A_{in}, B_i)} V_{i1} + V_{i2} .$$

In addition, the individually optimal vote of a new producer in period 2, $(a_{i2}^*, A_{in}^*; \theta_{i2})$, maximizes his income in period 2, V_{i2} . These votes are characterized by the first-order conditions of these two maximization problems. These conditions are identical to the FOC's $(a_{i1}), (a_{i2}), (A_{i1}), (A_{io}), (A_{in})$ and (B_i) , which are given in section 3.4.2: "Fixed patronage shares". As in section 3.4.2, these conditions also characterize the individually optimal votes of all producers in period 1 and 2 if a part (α) of the cost of the investment in an old cooperative is incurred in period 1 and a part $(1-\alpha)$ in period 2.

Again, FOC's $(A_{i1}), (A_{io}), (A_{in})$ and (B_i) imply that the individually optimal votes of an incumbent producer in periods 1 and 2 and of a new producer in period 2 satisfy the four conditions of the test on the Horizon Problem specified in section 3.3.3. Hence, an ownership structure with patronage rights resolves the Horizon Problem, no matter when the cost

of the investment is incurred, even if an investment pays off in multiple periods and if each member's share of the cooperative's patronage changes between these periods. In the next section, it is shown that this ownership structure also resolves the Horizon Problem if the payoff of an investment in period 2 is uncertain.

It could be shown that an ownership structure with patronage rights would be optimal as well if there were many periods, at the beginning of which the cooperative's members could make investments which would pay off from that period onwards, and at the end of which the cooperative's members could sell the right to supply their cooperative in perpetuity to prospective suppliers in the next period. In that case, the expected future profit which is due to an investment in a particular period would be incorporated in the market price of its patronage rights in that period.

3.5 Alternative Ownership Structures under Uncertainty

This section consists of two parts. Section 3.5.1 uses the single-period cooperative decision model to show that, if the members of a cooperative make their decisions concerning the cooperative's investment, its capacity and their own output simultaneously under uncertainty, they will make decisions which maximize their joint income, unless they are risk-averse. This confirms my claim in section 2.3.

Section 3.5.2 uses the two-period cooperative decision model to show what decisions a cooperative's members will make if they must choose the cooperative's equity investment before they know with certainty how this investment will affect their income, while they can choose its capacity and their own output once they are certain how these decisions will affect their income. Section 3.5.2 first shows that, if a cooperative's members adopt an ownership structure with revolving equity, they will disagree about the cooperative's optimal investment, even if the cooperative's members share the cost of this investment in proportion to their actual share of the cooperative's patronage in the period that this investment pays off. I refer to this problem as the Horizon Problem under uncertainty. This section then shows that this problem is resolved if the cooperative's members adopt an ownership structure with patronage rights. These results confirm my claims in sections 3.2.1 and 3.2.2.

3.5.1. Uncertainty in the single-period decision model

Suppose that there are many possible states of nature, denoted by t . T is the set of all states of nature. Each state affects the cooperative's profit through Φ_t , and the cost of production of a producer through θ_{it} . The cost of production of a producer in state t is $C_{it}(a_{it};\theta_{it})$, and the profit of a cooperative in state t is $P_{jt}(A_{jt},B_{jt};\Phi_t)$. It is assumed that C_{it} and P_{jt} have the same properties as those specified in the single-period model without uncertainty. [chapter 2.2: exh 1] Z_t is the set of producers who supply a cooperative in state t , as defined in section 2.3.

The chance that a particular state of nature will occur is $f_{it}(\Phi_t, \theta_{it})$, with domain $[0;1]^2$. The probability distribution of Φ_t , $\int f_{it} d\theta_{it}$, is written as f_Φ , while the probability distribution of θ_{it} , $\int f_{it} d\Phi_t$, is written as f_θ . I assume that the distribution of Φ_t , f_Φ , is the same for each producer and that all producers observe and agree on the actual realization of Φ_t . However, the distribution of θ_{it} , f_θ , may not be the same for all producers. Furthermore, producers may not all be of the same type in any particular state.

Now suppose that a cooperative's members must choose its capacity and its investment as well as their own output before the actual state of nature is known. In that case, the cooperative's expected net profit is:

$$E_j(P_{jt} - rB_j) = \int [P_{jt}(A_j, B_j; \Phi_t) - rB_j] f_\Phi d\Phi_t ,$$

and each member's expected production cost is:

$$E_i(C_{it}) = \int C_{it}(a_i; \theta_{it}) f_{\theta} d\theta_{it} .$$

Given the assumptions on P_{jt} and C_{it} , the cooperative's expected net profit, $E_j(P_{jt} - rB_j)$, is strictly quasi-concave in (A_j, B_j) and a producer's expected cost of production, $E_i(C_{it})$, is strictly convex in a_i . Hence, Propositions 1 and 2 of chapter 2 apply directly, and the cooperative's optimal profit-sharing rule in each state of nature is:

$$T_{it}(a_i, A_i, B_i) = \frac{a_i}{A_i} [P_{it} - rB_i].$$

This implies that each member's share of the cooperative's expected net profit equals his share of its patronage. In that case, the cooperative's members will unanimously agree on its optimal capacity, which maximizes its expected net profit per unit of patronage, and on its optimal investment, which maximizes its expected net profit, given its capacity.

It must be pointed out, however, that, in contrast to the single-period model with certainty, profit-sharing in proportion to patronage may not be optimal if producers are risk-averse. This can be demonstrated by examining each member's expected utility of income, $E_i(U_{it})$ which equals:

$$E_i(U_{it}) = \iint U_{it}(V_{it}; I_i) f_{it} d\theta_{it} d\Phi_t , \text{ where}$$

$$V_{it} = \frac{a_i}{A_i} [P_{it} - rB_i] - C_{it} .$$

and where I_i is a producer's inobservable income preference. If $U_{it}(V_{it}; I_i)$ is strictly concave in V_{it} and if there are multiple states of nature, the cooperative's members will weigh the marginal profit of the cooperative with respect to A_i and B_i in each state differently, depending on their share of the cooperative's patronage. This is true even if all producers have the same income preference I_i , as long as each producer's type θ_{it} is not the same as that of all other producers in each period. As a result, they will disagree on the cooperative's optimal policies (A_i^*, B_i^*) , unless each member's marginal utility of income is the same as that of all other members in each state. That is, unless $U_{it}^V = U_{jt}^V$, $\forall t \in T$, $\forall i \in N$, $\forall j \in N$.

3.5.2. Uncertainty in the Two-Period Cooperative Model

Now suppose instead that a cooperative's members must choose its initial investment before they know how this investment will affect its profit and that they can choose the cooperative's capacity as well as their own output once they know how these decisions will affect the cooperative's profit and their production cost. This situation can be analyzed using the two-period cooperative decision model described in section 3.3, with the added assumption that a cooperative's investment in period 1 only increases its profit in period 2, not in period 1. It is assumed that all producers are risk neutral.

Suppose that there are two periods, period 1 and period 2. There is only one state of nature in period 1, but there are many possible states of nature in period 2. In period 1, a producer's cost of production, $C_{i1}(a_{i1};\theta_{i1})$, depends on his output a_{i1} given his type in period 1, θ_{i1} . A cooperative's profit, $P_{j1}(A_{j1};\Phi_1)$, depends on its capacity, A_{j1} , given the exogenous factor Φ_1 . In period 2, the actual cost of production of each producer in state t , $C_{it}(a_{it};\theta_{it})$, depends on his output in state t , a_{it} , given his type in state t , θ_{it} . The actual profit of an old cooperative in state t , $P_{jot}(A_{jot};B_j,\Phi_t)$, depends on its actual capacity in state t , A_{jot} , given its initial investment in period 1, B_j , and an exogenous factor in state t , Φ_t . The profit of a new cooperative in state t , $P_{jnt}(A_{jnt};0,\Phi_t)$ depends on its

capacity in state t , A_{nt} , given Φ_t . The joint probability distribution of Φ_t and θ_{it} is the same as the one in the single-period cooperative decision model with uncertainty. It is assumed that C_{i1} , C_{it} , P_{j1} , P_{jot} and P_{jnt} have the properties specified in section 3.3.1.

Because of the uncertainty regarding period 2, the voting procedure is somewhat different from that used in section 3.4. In contrast to section 3.4, it is assumed that the producers in period 1 choose their own output as well as the capacity and the investment in their cooperative in period 1, but not the capacity of their cooperative in period 2, before the actual state of nature in period 2 is known with certainty. A producer's vote in period 1 is denoted by (a_{i1}, A_{i1}, B_i) . In period 2, an incumbent producer chooses his own output level and the capacity of an old cooperative and a new cooperative in each state of nature, once the actual state of nature in period 2 is known with certainty. This vote is denoted by $(a_{it}, A_{iot}, A_{int})_{t \in T}$. A new producer in period 2 chooses his own output and the capacity of a new cooperative in each state. His vote is denoted by $(a_{it}, A_{int})_{t \in T}$. This two-period cooperative decision model with uncertainty can be used to compare what decisions a cooperative's members will make under two alternative ownership structures, one with revolving equity and one with patronage rights.

Revolving Equity

As is explained in section 3.4.1, the members of a cooperative which has an ownership structure with revolving equity and profit-sharing in proportion to patronage share the equity cost of the cooperative's investment in the period that this cost is incurred and they share the contribution of that investment to the cooperative's profit in the period that this investment pays off.

In the ownership structure examined in this subsection, the cost of a cooperative's investment in period 1 is shared by the suppliers of that cooperative in period 2, when this investment pays off. In each state of nature in period 2, a member of a cooperative shares its profit and the cost of its investment in proportion to his actual share of the cooperative's patronage in that state.

Knoeber and Baumer [1983, p.33] claim that this method of sharing the cost of a cooperative's investment resolves the cooperative Horizon Problem. As was shown in section 3.4.1, this claim may be correct if the payoff in period 2 of an investment in the cooperative is known with certainty in period 1, because this method of cost-sharing satisfies condition (1c) stated in that section. However, I show below that this claim is incorrect if the payoff of a cooperative's investment is not known with certainty. The cause of this problem is that each member of the cooperative in period 1

weighs the cooperative's marginal profit of investment in each state in period 2 differently, depending on his share of the cooperative's patronage in that state.

As in the ownership structure with revolving equity described in section 3.4.1, I assume that the incumbent members of an old cooperative in period 2 can choose whether to supply an old or a new cooperative in each state in period 2. As was mentioned in section 3.4, this is necessary because in this ownership structure, the producers in period 2 may not be indifferent between supplying an old or a new cooperative. I also assume that the optimal aggregate capacity of the old cooperatives in each state in period 2 is large enough to accommodate the aggregate optimal output of all incumbent producers in that state, if they choose to supply an old cooperative. In addition, the incumbent producers may admit some new producers to an old cooperative in any state to fully use its capacity in that state.

In that case, an incumbent member of an old cooperative earns in period 1:

$$V_{i1}(a_{i1}, A_{i1}, B_i; \theta_{i1}) = \frac{a_{i1}}{A_{i1}} P_{i1}(A_{i1}; \Phi_1) - C_{i1}(a_{i1}; \theta_{i1}).$$

If that producer supplies an old cooperative in state t , he earns $V_{iot}(a_{iot}, A_{iot}; \theta_{it})$, which equals:

$$V_{iot} = \frac{a_{iot}}{A_{iot}} [P_{iot}(A_{iot}; B_i, \Phi_t) - rB_i] - C_{it}(a_{iot}; \theta_{it}).$$

where a_{iot} denotes his individual output if he supplies an old cooperative in state t .

If that producer supplies a new cooperative in state t instead, he earns:

$$V_{int}(a_{int}, A_{int}; \theta_{it}) = \frac{a_{int}}{A_{int}} P_{int}(A_{int}; 0, \bar{\Phi}_t) - C_{it}(a_{int}; \theta_{it}),$$

where a_{int} denotes his individual output if he supplies a new cooperative in state t .

In that case, the individually optimal votes of an incumbent producer in period 1, $(a_{i1}^*, A_{i1}^*, B_i^*; \theta_{i1}, (\theta_{it})_{t \in T})$, and in period 2, $(a_{iot}^*, a_{int}^*, A_{iot}^*, A_{int}^*; \theta_{i1}, \theta_{it})_{t \in T}$, solve the following maximization problem:

$$\text{MAX}_{(a_{i1}, A_{i1}, B_i, (a_{iot}, a_{int}, A_{iot}, A_{int})_{t \in T})} V_{i1} + \iint V_{it} f_{it} d\theta_{it} d\bar{\Phi}_t$$

where V_{it} equals $\max(V_{iot}, V_{int})$.

These votes are characterized by the first-order conditions of this maximization problem in period 1 and in each state of nature in period 2:

$$(a_{i1}) \frac{P_{i1}}{A_{i1}} - C_{i1}^a = 0 ,$$

$$(a_{iot}) \frac{1}{A_{iot}} [P_{iot} - rB_i] - C_{it}^a = 0 ,$$

$$(a_{int}) \frac{P_{int}}{A_{int}} - C_{it}^a = 0 ,$$

$$(A_{i1}) \frac{a_{i1}}{A_{i1}} [P_{i1}^A - \frac{P_{i1}}{A_{i1}}] = 0 ,$$

$$(A_{iot}) \frac{a_{iot}}{A_{iot}} [P_{iot}^A - \frac{P_{iot} - rB_i}{A_{iot}}] = 0 ,$$

$$(A_{int}) \frac{a_{int}}{A_{int}} [P_{int}^A - \frac{P_{int}}{A_{int}}] = 0 ,$$

$$(B_i) \iint \frac{a_{iot}}{A_{iot}} [P_{iot}^B - r] f_{it} d\theta_{it} d\bar{\theta}_t = 0 ,$$

where $a_{iot}^* \geq 0$ if $V_{iot}(a_{iot}^*, a_{int}^*, A_{iot}^*, A_{int}^*; \theta_{it}) \geq 0$

and if $\frac{P_{iot}^* - rB_i^*}{A_{iot}^*} \geq \frac{P_{int}^*}{A_{int}^*}$.

A new producer in state t in period 2 earns $V_{iot}(a_{iot}; \theta_{it})$ if he supplies an old cooperative with a given capacity and

investment and $V_{int}(a_{int}, A_{int}; \theta_{it})$ if he supplies a new cooperative. Hence the individually optimal vote of a new producer in period 2, $(a_{iot}^*, a_{int}^*, A_{int}^*; \theta_{i1}, \theta_{it})_{t \in T}$, is characterized by the FOC's (a_{iot}^*) , (a_{int}^*) and (A_{int}^*) .

FOC's (A_{i1}) , (A_{iot}) and (A_{int}) show that, if all producers in period 1 agree on a cooperative's optimal investment B_i^* , they will unanimously choose an optimal capacity of a cooperative in period 1 and the incumbent producers in state t in period 2 will unanimously choose a capacity of an old and a new cooperative in each state of nature in period 2 which maximizes its net profit per unit of patronage in that state. However, FOC(B_i) shows that the producers in period 1 will disagree about the cooperative's optimal investment in period 1, unless each member's share of the cooperative's patronage is constant over all states of nature and unless the chance that a particular state of nature occurs, $f_{it}(\theta_{it}, \Phi_t)$, is the same for each producer, because each member weighs the cooperative's marginal profit of investment in each state in period 2 with his actual share of the cooperative's patronage in that state. Hence, if the majority of the producers in period 1 expects to supply a relatively small share of the patronage of an old cooperative in the states that the payoff of the investment in that cooperative is relatively high, they will underinvest in the cooperative. This is the Horizon Problem under uncertainty.

Patronage Rights

To resolve the cooperative Horizon Problem under uncertainty, the members of a cooperative can adopt an ownership structure with patronage rights, instead of the ownership structure with revolving equity described above. As before, it is assumed that the members of an old cooperative in period 1 can sell the right to supply their cooperative in period 2 to producers in period 2. Assuming that demand for patronage rights is competitive, the maximum price the member of a cooperative in period 1 can charge its suppliers in state t of period 2 is:

$$\frac{P_{iot}}{A_{iot}} = \frac{P_{nt}^*}{A_{nt}^*},$$

where A_{nt}^* is the unanimous vote of all producers for the capacity of a new cooperative in state t , and P_{nt}^* equals $P_{nt}(A_{nt}^*; 0)$.

If all cooperatives in both periods adopt profit-sharing in proportion to patronage, an incumbent member of an old cooperative earns in period 1:

$$V_{i1}(a_{i1}, A_{i1}, B_i; \theta_{i1}) = \frac{a_{i1}}{A_{i1}} [P_{i1} - rB_i] - C_{i1}.$$

Given the competitive price of a patronage right, that producer earns $V_{it}(a_{it}, A_{iot}, A_{int}; \theta_{it})$ in period 2, state t , which equals:

$$V_{it} = \frac{a_{it}}{A_{it}} [P_{iot} - A_{iot} \frac{P_{nt}^*}{A_{nt}^*}] + \frac{a_{it}}{A_{int}} P_{int} - C_{it}.$$

A new producer in period 2 does not sell any patronage rights.

He earns in state t :

$$V_{it}(a_{it}, A_{int}; \theta_{it}) = \frac{a_{it}}{A_{int}} P_{int} - C_{it}.$$

In that case, the individually optimal votes of an incumbent producer in period 1, $(a_{i1}^*, A_{i1}^*, B_i^*; \theta_{i1})$, and in period 2, $(a_{it}^*, A_{i0t}^*, A_{int}^*; \theta_{it})_{t \in T}$, solve the following maximization problem:

$$\text{MAX}_{(a_{i1}, A_{i1}, B_i, (a_{it}, A_{i0t}, A_{int})_{t \in T})} V_{i1} + \iint V_{it} f_{it} d\theta_{it} d\bar{\theta}_t.$$

These votes are characterized by the first-order conditions to this maximization problem:

$$(a_{i1}) \frac{1}{A_{i1}} [P_{i1} - rB_i + \int [P_{i0t} - A_{i0t} \frac{P_{nt}^*}{A_{nt}^*}] f_{\bar{\theta}} d\bar{\theta}_t] - C_{i1}^a = 0,$$

$$(a_{it}) \frac{P_{int}}{A_{int}} - C_{it}^a = 0,$$

$$(A_{i1}) \frac{a_{i1}}{A_{i1}} [P_{i1}^A -$$

$$\frac{1}{A_{i1}} [P_{i1} - rB_i + \int [P_{i0t} - A_{i0t} \frac{P_{nt}^*}{A_{nt}^*}] f_{\bar{\theta}} d\bar{\theta}_t] = 0$$

$$(A_{i0t}) \frac{a_{i1}}{A_{i1}} [P_{i0t}^A - \frac{P_{nt}^*}{A_{nt}^*}] = 0,$$

$$(A_{int}) \frac{a_{it}}{A_{int}} [P_{int}^A - \frac{P_{int}}{A_{int}}] = 0,$$

$$(B_i) \frac{a_{i1}}{A_{i1}} [\int P_{i0}^B f_{\bar{\theta}} d\bar{\theta}_t - r] = 0.$$

In addition, the individually optimal vote of a new producer in period 2, $(a_{it}^*, A_{int}^*; \theta_{it})$, maximizes his income in period 2, V_{it} . This vote is characterized by FOC's (a_{it}) and (A_{int}) given above. If a cooperative's investment in period 1 pays off both in period 1 and in period 2, FOC(B_i) is replaced by FOC(\hat{B}_i):

$$(\hat{B}_i) \frac{a_{i1}}{A_{i1}} [P_{i1}^B + \int P_{iot}^B f_{\Phi} d\Phi_t - r] = 0.$$

FOC's $(A_{i1}), (A_{iot}), (A_{int}), (B_i)$ and (\hat{B}_i) imply that the individually optimal votes of an incumbent producer in periods 1 and 2 and of a new producer in period 2 satisfy the four conditions of the test on the Horizon Problem specified in section 3.3.3, where the fee paid by the suppliers of an old cooperative in period 2 to the members of that cooperative in period 1 in the two-period cooperative model with certainty is replaced by the expected fee in FOC's (a_{i1}) and (A_{i1}) . This expected fee equals:

$$\int \text{MAX}_{A_{iot}} [P_{iot}(A_{iot}; B_i) - \text{MAX}_{A_{int}} \frac{A_{iot}}{A_{int}} P_{int}] f_{\Phi} d\Phi_t .$$

Hence, an ownership structure with patronage rights resolves the Horizon Problem. The reason for this is that the members of a cooperative in period 1 weigh the marginal profit of investment with their share of the cooperative's patronage in period 1, instead of with their actual share of its patronage in each state in period 2.

3.6 Moral Hazard and Patronage Rights

This section argues that, if a cooperative does not have an ownership structure with patronage rights, its cost of attracting outside equity may be higher than that of an investor-owned firm and that it cannot structure its management incentives as efficiently as an investor-owned firm, because its members can manipulate its profit. I then argue that these problems can be resolved if a cooperative adopts an ownership structure with patronage rights.

Outside Investment and Cooperative Moral Hazard

In the cooperative decision model described in chapter 2, it was assumed that the cooperative's members must provide its equity, which is used to finance the cooperative's investment in assets which may increase its profit. However, if a member of a cooperative is more wealth-constrained than outside investors, he could attract part of the equity he contributes to the cooperative from outside investors, in exchange for a dividend, which is a part of his share of the cooperative's profit. In that case, the optimal profit-sharing rule identified in chapter 2 still applies, and the individual optimization problem of that member is:

$$\begin{aligned} \text{MAX}_{(a_i, A_i, B_i, s_i)} & \frac{a_i}{A_i} (1-s_i)P_i - C_i \\ \text{s.t.} & \frac{a_i}{A_i} (s_i P_i - rB_i) \geq 0, \text{ where} \end{aligned}$$

$\frac{a_i}{A_i} B_i$ is equity invested in the cooperative by the
 outside investor on behalf of member i.
 s_i is the part of member i's share of the
 cooperative's profit which he pays to the investor
 r is the cost of equity to an outside investor.

In that case, all members will unanimously agree on a
 cooperative capacity and investment (A^*, B^*) which maximize the
 cooperative's net profit per unit of patronage, assuming that
 they all have access to outside investors with the same cost
 of equity. Similarly, if a member of a cooperative is more
 risk-averse than outside investors, he may want to sell his
 entire share of the cooperative's profit in exchange for a
 lump sum payment, part of which he would agree to invest in
 the cooperative.

Thus, outside investment in the cooperative does not by itself
 change the results of the model presented in chapter 2. In
 fact, a number of cooperatives in the United States have
 raised equity by selling a minority share in their marketing
 subsidiaries on the stock market. [Brown, 1988] For example,
 Land O'Lakes raised \$13 million in equity by selling a 32%
 equity interest in its Country Lake Foods Division in 1988.
 [ch 4:p 5]

I repeat that the cooperative's profit is defined as its net
 revenues minus its costs, before any payments have been made

to the cooperative's members for the product they supply to it. Hence, the members of such a cooperative cannot short-change the outside investors simply by raising the price the cooperative pays its members for the product they supply.

However, if outside investors earn a part of the cooperative's profit, its members might surreptitiously take certain actions which could reduce the cooperative's profit, at the expense of the outside investors who share this profit. This cooperative moral hazard problem is similar to the moral hazard problem in a management-owned firm, as described by Jensen and Meckling [1976]. For example, the members of the cooperative could reduce the quality of the product they supply to the cooperative compared to the quality they would supply if they earned its entire profit themselves. The cooperative's members would do this if their share of the reduction of the cooperative's profit was smaller than the reduction of their private production costs, due to the reduction in product quality.

If the outside investors anticipate this problem, and if it is not possible to prevent such behavior by contract, they will not pay as much for a share of the cooperative's profit as they will for a share of the profit of a similar investor-owned firm, whose owners cannot manipulate the cooperative's profit in this way, because they do not trade with the firm.

To prevent this problem, a cooperative might attract outside investment by establishing a joint-venture with a private firm. In that case, the private firm markets the cooperative's product and it invests in market development to add value to the cooperative's product. The cooperative earns a share of the firm's net profit from marketing the cooperative's products. Goldberg [1972] provides several examples of such joint-ventures.

However, a converse moral hazard problem may arise in this case. The firm might reduce its inobservable effort to market the cooperative's product, compared to its effort if it did not share its profit with the cooperative. It would do so if such a reduction in its marketing efforts increased its profit minus the cost of its inobservable marketing efforts, even if this reduced its profit from marketing the cooperative's products, which were shared with the cooperative.

I conclude that the cost of attracting equity from outside investors for a cooperative may be higher than the cost of attracting outside equity for an investor-owned firm, because of the moral hazard problem described above. If this problem is not resolved, a cooperative will attract less equity from outside investors than an investor-owned firm. As a result, the cooperative will invest less in assets which must be financed with equity, including intangible assets, such as product and market development. This reduces its members'

income relative to what they can earn if they supply another firm instead of the cooperative. However, I will argue in the last subsection that this problem can be resolved if the cooperative adopts an ownership structure with patronage rights.

Management Effort and Cooperative Moral Hazard

A very similar problem as the one described above may arise between a cooperative's members and its management. Suppose that a cooperative's management can make an effort to enhance the profitability of the cooperative, but that this effort cannot be observed by its members.

As Holmstrom [1979] explains, an investor-owned firm can stimulate its management to make an inobservable effort by rewarding it with a share of the firm's profit. This share depends on the predictability of the effect of management's effort on the profit of the firm and on the risk-aversion of management. Such incentives do not stimulate the firm's management to make as much effort as it would if the firm's owners could observe this effort directly, unless management is risk-neutral or the effect of management effort on the firm's profit is certain. However, the firm's owners will generally make more profit if they provide some profit-related incentives than if they provide no incentives at all.

To stimulate the inobservable effort of its management, a cooperative could provide profit-related incentives to it as well. However, a cooperative cannot structure such incentives as efficiently as a private firm can, because of the cooperative moral hazard problem described above.

Specifically, suppose that the cooperative stimulates its management's efforts to improve its future profitability with a share of its future profit. Once management has made this effort, the members could increase their net income by reducing the quality of the product they supply to it. This would reduce the cooperative's profit at the expense of its management which shares this profit. If the cooperative's management anticipates this moral hazard problem, it will make less effort to increase the cooperative's profit for a given share of its profit than if this problem did not exist. Again, a converse moral hazard problem arises if the cooperative's management can choose the quality of the product which its members supply to the cooperative.

If a cooperative cannot resolve this problem, it will give its management fewer profit-related incentives than an investor-owned firm and it will invest less in activities whose profitability depend on the inobservable effort of its management. Such activities typically include management of intangible assets, like product and market development. In addition, such a cooperative will tend to attract management which is less qualified than the management of a comparable

investor-owned firm, because it cannot reward its skills as efficiently as an investor-owned firm can. Finally, to compensate for the inefficiency of its management incentives, a cooperative's members will monitor its management more intensively than the owners of an investor-owned firm.

This hypothesis is partly confirmed by Caswell [1987], who has observed that the boards of directors of the cooperatives in her sample of firms in agribusiness had fewer outside directors, and thus more direct owner-representation, than the investor-owned firms in her sample.

Moral Hazard and Patronage Rights

The cooperative moral hazard problem described above arises because the net income of a member of a cooperative consists of an observable part, his share of the cooperative's profit, and an inobservable part, his production cost. If a non-member, such as an outside investor or the cooperative's management, shares only in the cooperative's profit, its members have an incentive to reduce the observable part of their income in favor of the inobservable part, at the expense of the non-member.

Now suppose that there exists a competitive market for patronage rights. If the cooperative's members reduce the quality requirements on the product they supply to the cooperative, to increase their net income, the cooperative's

profit declines, reducing the market price of these rights. However, this reduction in the cooperative's quality requirements also reduces the cost of supplying the cooperative, which increases the market price of these rights. In other words, the market price of patronage rights depends on the total net income of a member of the cooperative, including his observable share of its profit and his inobservable cost of production, given the quality requirements on the product he supplies to the cooperative.

Hence, if the cooperative ties the dividends of its outside equity investors as well as its management incentives to the market price of these rights, its members cannot make themselves better off by reducing the observable part of their income in favor of the inobservable part, at the expense of outside investors and its management. Therefore, this method of rewarding outside investors and management resolves the moral hazard problem described above.

I conclude that, if a cooperative adopts an ownership structure with patronage rights, it can attract equity from outside investors at the same price as an investor-owned firm and it can structure its management incentives as efficiently as such a firm. This enables the cooperative to compete more successfully in activities which require large investments in intangible assets.

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