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### **Explaining Cooperative Enterprises through Knowledge Acquisition Outcomes**

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# Explaining Cooperative Enterprises through Knowledge Acquisition Outcomes\*

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## Abstract

This paper develops a formal model of a cooperative enterprise which explains why cooperatives are present in such a large number of sectors. In our model of a multi-stage production process, we account for the possibility that producers can acquire knowledge to decrease their cost of production. We distinguish between knowledge that can be generalized among producers, and knowledge that cannot be generalized and therefore is idiosyncratic to each production site. We compare the cooperative's outcomes with simple models of a vertically separated market of autonomous producers and of a centralized hierarchy consisting of fully owned subsidiaries. To conduct a meaningful comparison, we establish equilibrium outcomes for knowledge acquisition, output, and profits generated in each organizational arrangement. From the comparison, we derive parameter constellations, under which the cooperative outperforms the market and hierarchy forms of business organization. This article contributes to the organizational economic analysis of cooperatives and provides a model that illustrates the competitive advantages of cooperatives in the market-hierarchy continuum.

**Keywords:** Cooperative; hierarchy; market; organizational knowledge; knowledge acquisition

**JEL Classification:** D83; L22

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# 1 Introduction

Cooperatives exist worldwide and in a broad range of sectors. The cooperative model of organization dominates many business sectors such as agriculture, financial services, housing, sports, transportation (taxis, buses, etc.), and utilities (electricity, water, gas, etc.). According to the United Nations and the International Cooperative Alliance ([www.ica.coop](http://www.ica.coop)), over 1 billion people worldwide are members of cooperatives. In many countries, entire industries are dominated by cooperatives. In the United States, more than 30'000 cooperatives generate combined annual revenues in excess of US\$ 500 billion. In continental Europe, the cooperative banks that are members of the European Association of Cooperative Banks have 130 million customers, 4 trillion euros in assets, and 17% of Europe's deposits. In Switzerland, the cooperative Migros is the country's largest employer. Around the world, cooperatives provide over 100 million jobs, 20% more than multinational enterprises. The proclamation by the United Nations of the year 2012 as the International Year of Co-operatives underlines the wide-spread presence and importance of cooperatives.<sup>1</sup> Despite their importance, economic explanations for their existence and wide-spread presence, as well as discussions of their potential advantages over other organizational arrangements have been inconclusive.

In this paper, we develop a formal model of a cooperative enterprise and compare it with a vertically separated market and a hierarchy consisting of vertically integrated subsidiaries to illustrate how advantages of the cooperative form of organizing emerge. The literature provides few and often contradictory assessments of the competitiveness of cooperatives. For example, Hansmann (1988) compares conventional investor-owned firms with cooperatives. He concludes that market contracts are costly in cases of asymmetric information or market power. Under these circumstances, a union of firms might reduce costs. Hendrikse & Veerman (2001) analyze the influence of the organizational structure on a cooperative's ability to attract outside equity. They show that cooperatives have a disadvantage against conventional firms with respect to access to equity funds. As a consequence, cooperatives can only prevail against conventional firms as long as the asset specificity at the processing stage of production is low. Some authors point at the public support enjoyed by cooperatives in some countries and industries. For example, cooperatives frequently face lower taxes, subsidized interest rates and protected markets to give cooperatives advantages via market power (Sexton & Iskow 1993*a*, Cook 1995). Hendrikse (1998) derives parameter constellations under which investor-owned firms' superior performance compared to cooperatives may be countered by the favorable public policy treatment of cooperatives. However, other authors consider these advantages as corrections of government-imposed restrictions on cooperatives' operations (Nilsson 2001). Additionally, the variety of cooperatives that receive such favorable conditions does not allow inferences whether public support fosters inefficiency or encourages efficient production of valuable goods.

Feng & Hendrikse (2011) develop a multi-task principal-agent model to compare cooperatives and investor-owned firms. They come to the conclusion that an interdependency between stages of production may give cooperatives a competitive advantage if there are complementarities between the production stages and the value added at the downstream value added does not exceed a certain level. This implies that cooperatives outperform investor-owned firms in industries where the processing stage's contribution to the overall value of a product isn't too high. Porter & Scully (1987) and Ferrier &

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<sup>1</sup>See <http://social.un.org/coopsyear>.

Porter (1991) compared the productive efficiency of cooperatives with investor-owned firms, with the conclusion that cooperatives show, among others, greater amounts of technical/X-inefficiency, that an increase in cooperative size increases the problem of control, and that cooperatives are not expected to fully realize all scale economies. In contrast, Helmberger & Hoos (1962) state that the cooperative and an investor-owned firm faces the same marginal conditions, implying identical outcomes. In their survey on the economic efficiency of cooperatives, Sexton & Iskow (1993b) derive that there is no evidence that cooperatives are less efficient than comparable investor-owned firms. In contrast to the frequent popular perception that cooperatives are less efficient, Bogetoft (2005) shows that, given particular market parameters and output characteristics, cooperatives outperform a vertically separated value chain as a consequence of information asymmetries that cause inefficiencies in vertically separated arrangements. In his model he does not account for potential conflicts of interest among the members of the cooperative and the model only allows outcomes where the cooperative never performs worse than an investor-owned processor.<sup>2</sup>

To the best of our knowledge, none of these studies attempts a simultaneous comparison of cooperatives with hierarchies and markets. Additionally, we believe that theoretical models of cooperatives have neglected the interaction of organizational form and knowledge acquisition as an argument for the competitiveness of cooperatives. Our model tries to fill this gap. We show that cooperatives can have a competitive advantage over both organizational arrangements stemming from their particular allocation of ownership rights and the resulting incentives to acquire knowledge. We formulate a simple model of the production of a good and the transaction of the good from the producers to a processor, where both producers and processor are risk-neutral. We consider two types of producers, with each producer operating an independent production site. The producers differ in their marginal costs of production. After production, the producers sell their output to a processor, who transforms the raw product into the final product and sells it to end consumers in a competitive market.<sup>3</sup> The organization of the individual sites and their relationship to the processor determine production and transaction costs. We assume that the production technology is identical for all forms of organization. We focus on the cooperative's mode of organizing production and processing activities, and compare this organizational arrangement with the outcomes of market and hierarchy. In our analysis, we put special emphasis on agents' decisions to acquire generalizable and non-generalizable, specific knowledge in the production process and in decision making about output levels.

Furthermore, we assume a processor with market power vis-a-vis the producers. Market power is a frequently observed phenomenon at the processing stage, e.g., in the agricultural sector. Market power in this context can have different reasons. Some authors name the specific investments of producers and their subsequent dependence on a processor that is located in the proximity of their production sites (See Bonus (1986) and Staatz (1987), for example). Another explanation, related to the specific investment argument, could be the economic nature of processing. To process a raw input, a processing plant is necessary, which generally allows to process input at low variable costs. This combination of substantial fixed costs and small variable costs favors the emergence

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<sup>2</sup>Further, Bogetoft (2005) does not consider the possibility of knowledge acquisition, but focuses on a given information asymmetry. We address this aspect below.

<sup>3</sup>See Hendrikse (2007) for an analysis of the interaction between an upstream and a downstream party and the coexistence of different forms of governing the resulting transactions.

of market power on the side of the processor. We incorporate this aspect in our model via a single processor that operates at a combination of fixed and variable cost.<sup>4</sup>

We consider agents who can acquire knowledge, but face costs of knowledge acquisition, with different acquisition costs depending on the type of knowledge.<sup>5</sup> In particular, we model the acquisition of specific, generalizable and specific, non-generalizable knowledge as costly, but not impossible.<sup>6</sup> A lack of specific knowledge on the part of the decision maker causes a higher cost of production and thus has consequences on output and profits.

Our model, which incorporates the combination of market-like incentives and hierarchy-like cost advantages, allows the cooperative enterprise to exploit knowledge that reduces the cost of production to an extent that this mode of organization can generate output at lower cost, as well as achieve higher aggregate profits than the polar forms of organizing transactions, i.e., markets and hierarchies. We illustrate the influence of what Bonus (1986) calls the centripetal and centrifugal forces in cooperatives: forces, which pull the members together as one organization, and forces which induce the members to remain independent units because there are advantages to individual operation. We model these forces in terms of coordinated investments and of acquiring and applying knowledge in organizations.

The paper is structured as follows. In Section 2, we provide the theoretical foundations. First, we give a short overview of the organizational attributes of cooperatives. Second, we define the taxonomy of knowledge that we consider in our analysis. In Section 3, we introduce a basic model of production that includes the influence of knowledge on costs. We then illustrate knowledge acquisition behaviors and their consequences on output and profits in different organizational arrangements. Section 4 compares different organizational arrangements with respect to their knowledge acquisition, as well as the aggregate output generated and profits obtained by producers and processor. Section 5 concludes.

## 2 Theoretical foundations

### 2.1 Organizational attributes of the cooperative enterprise

Cooperatives, due to their adaptation to different market situations and the related evolution over time, are hard to define in a tightly prescriptive way (Hind 1999). Hart & Moore (1996) rudimentarily define a member's cooperative as an enterprise, where the members who take decisions democratically on a one-member, one-vote basis, control the assets of the exchange. However, they point out that this is a drastic simplification of a cooperative organization. In reality, many specific organizational parameters can be and are incorporated in a cooperative. Theoretical analysis of cooperatives and possible problems of this organizational arrangement call for the definition of basic attributes common to all types of cooperatives. We therefore characterize cooperative enterprises

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<sup>4</sup>See Sexton (1986) for the relevance of this approach. In contrast, e.g., Bogetoft (2005) considers a cooperative, where the processor does not face any costs.

<sup>5</sup>We thus do not consider the distribution of knowledge at the production sites as exogenous, as opposed to Bogetoft (2005), who models a given asymmetry of information among agents.

<sup>6</sup>Generalizable and non-generalizable knowledge that is general by definition is easily observable and can be transferred at low (in our case zero) cost (Jensen & Meckling 1995). We therefore do not focus on general costs in our analysis.

by a number of organizational attributes.

All cooperatives share that they are a form of vertical integration (Sexton 1984). By integration, a collective of individuals attempts to effect changes to make market conditions more favorable and use hierarchy-like instruments like common staff and administrative controls (Chaddad & Reuer 2009). The changes, which cooperatives effect to their favor, may concern the countering of market power, eliminating hold-up problems, or improving employment security. Apart from the vertical integration, cooperatives also show several market-like features, e.g., decentralized decision-making and market-driven incentives to efficiency (Makadok & Coff 2009). This mixture of hierarchy and market-related attributes makes a cooperative a hybrid form of organization (Menard 2004).

In cooperatives, there exists a unique relationship between the owners and the enterprise. For example, in a processing cooperative, owners are not only investors in an enterprise, but also its suppliers. Apart from the fact that the owners of the enterprise are also its suppliers, other principles define a cooperative. The suppliers of the enterprise are also the control authority and receive the benefits of the cooperative (Barton 1989, Novkovic 2008). Another important characteristic of a cooperative is that it is owned by a number of members that do not have individual ownership rights to the cooperative (Nilsson 2001). Cooperatives frequently dispose of unallocated equity capital, capital that is collectively owned and subject to collective decision-making. The collective ownership has various consequences with respect to agency issues, because the members generally cannot sell shares in a cooperative at a market price (Jensen & Meckling 1979). Collective decision-making over assets implies the trade-off the members face when they form a cooperative enterprise. There is a need that the individual members forego some of their sovereignty to establish and benefit from the cooperative entity, at the same time the members remain economically sovereign economic units (Phillips 1953).

The specific form of separation of ownership and control in cooperative enterprises gives rise to a number of problems with respect to investment decisions in traditional cooperatives. The literature summarizes these as problems of “vaguely defined property rights”, which emerge because ownership of the cooperative’s assets is collective. (Cook 1995).<sup>7</sup> The effect of these problems on performance is stronger, the more members of a cooperative differ in their contribution to the cooperative’s cash flows, for example, and eventually the problems influence the investment behavior of cooperatives.<sup>8</sup> Consequently, although an investment may be profitable in a different organizational setting, its undertaking may fail in a cooperative due to the individual members’ decisions. In recent years, new cooperative models have emerged, which aim to mitigate different problems present in traditional cooperatives (Chaddad & Cook 2004).

In this article, we deploy a simple model of a cooperative where members receive a share of the cooperative’s profits according to their patronage, which we model as an exogenous fraction.<sup>9</sup> When the cooperative undertakes collective investments and coordination among the members is necessary, the one-member, one-vote principal determines collective decisions (Hart & Moore 1996). We assume that such a binding voting mechanism can resolve all coordination issues. Further, we consider the cooperative’s

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<sup>7</sup>For comprehensive discussion, also see Jensen & Meckling (1979), Vitaliano (1983), or Nilsson (2001).

<sup>8</sup>Other factors of influence on the problems of vaguely defined property rights are differences among members’ planning horizons, their risk attitudes, etc.

<sup>9</sup>See Cook & Chaddad (2004), e.g., for a characterization of different cooperative models and related patronage definition. An alternative modeling approach to ours is patronage that depends on the volume of delivery of a producer to the cooperative, see Phillips (1953) and Trifon (1961), for example.

membership to comprise all actors in a section of the economy, with no alternative outlet for a member's output, where membership in the cooperative is fixed. We treat delivery rights of member output as non-tradable and consider a setting where there is no side-trading among the producers.<sup>10</sup> Based on these assumptions, we compare the outlined cooperative's performance with the performance of independent producers interacting with a monopsony processor, and with the performance of vertically integrated producers acting as subsidiaries to the processor. The focus of our analysis thereby lies on the different knowledge acquisition behavior of agents in each organizational form.

## 2.2 Relevant types of knowledge in organizations

The quality of decisions in an organization depends on the relevant knowledge, and knowledge is frequently considered as the critical input in production processes (Grant 1996). There are many types of knowledge that are relevant to an organization. Among common categorizations of knowledge types are the distinction of general and specific knowledge (Jensen & Meckling 1995), and of knowledge that can be generalized as opposed to knowledge that is particular for one setting, i.e., non-generalizable (Sowell 1996).<sup>11</sup> With respect to the distinction between general and specific knowledge, we focus on knowledge, which is not easily observable and costly to transfer, i.e., specific knowledge. General knowledge, in contrast, is easily transferable at low cost and it can easily be observed by other agents (Jensen & Meckling 2009). An example for general knowledge is knowledge about the price and quantity of a particular good. Specific knowledge, in contrast to general knowledge, is difficult or impossible to observe by others (Jensen & Meckling 2009).

There are several types of specific knowledge, for example, idiosyncratic knowledge (e.g., knowledge about a specific location or machine) and scientific knowledge (e.g., linear algebra, astrophysics). Both general and specific knowledge are relevant in production processes. General knowledge, for example, is important for determining the cost-efficient combination of input factors. Specific knowledge is relevant to account for firm-specific parameters (for example, the quality of a farmer's soil or the preferences of a particular group of customers), and knowledge about particular production techniques (the optimal adjustment of a machine, for example).

Within the category of specific knowledge, we focus on the distinction between generalizable knowledge and knowledge that cannot be generalized. This distinction is the most appropriate for analyzing a number of individual producers on different production sites, where the producers are confronted with issues that may be common to each individual producer (certain machines, production techniques, etc.) and issues that are particular for each individual producer (infrastructure quality, soil conditions, etc.). The distinction implies that there can be significant differences between knowledge acquisition on different production sites.

In our analysis, we account for differences in the location of knowledge, its observability, as well as the cost of acquisition of generalizable and non-generalizable knowledge.

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<sup>10</sup>These assumptions are in line with seminal contributions to formal theory of cooperatives, e.g., Helmberger & Hoos (1962).

<sup>11</sup>Another categorization of knowledge has been the distinction of explicit, i.e., communicable, knowledge, and implicit, i.e., tacit, or incommunicable knowledge (Polanyi 1966). It has received much attention by economic research (Grant 1996, Spender 1996, Smith 2001). For the present analysis it is of influence insofar, as the distinction of implicit and explicit knowledge affects the cost of knowledge acquisition.

We assume two cost components that influence production costs for the producers, a general cost component and an idiosyncratic cost component. In order to optimally adapt to these cost elements, the decision-maker has to take the appropriate action, which is only possible with the relevant knowledge. This implies that judgement of the general and idiosyncratic cost elements is only possible to the extent that an agent acquires knowledge about these cost elements. Because of the nature of knowledge as a factor of production, any acquisition of generalizable knowledge and non-generalizable knowledge is an investment that cannot be recovered once undertaken (Arrow 1962). Consequently, by acquiring knowledge, the acquiring party simultaneously learns the utility and cost of knowledge.

It is important to address that the systematizations of general and specific, and of generalizable and non-generalizable knowledge is not dichotomic, but rather defines two ends of a continuum. Some business-relevant knowledge is more or less specific, and more or less particular to a firm than other knowledge. From an organizational perspective, particularly the distinction between generalizable and non-generalizable knowledge is critical. Forms of organization that are effective in using generalizable knowledge may be a complete failure in activities that require high amounts of knowledge that cannot be generalized.

Next, we introduce a model of organizational efficiency with respect to knowledge acquisition, where different organizational arrangements set differing conditions for the acquisition of generalizable and non-generalizable knowledge, and we analyze organization outcomes based on these conditions.

### 3 A simple model of organizational efficiency

In this section, we compare three organizational arrangements regarding their knowledge acquisition, production decisions, and their profits. First, we present the model of a cooperative enterprise, where the producers jointly own the processor. In the second arrangement, all producers act autonomously as independent firms. That is, they do not cooperate, and the market is vertically separated. The processor also acts self-governed as a buyer of the output of the producers. We will call this case the market form of business organization because all interactions of agents are bilateral and autonomous. Third, we examine the outcome in a vertically integrated market, where the processor controls the producers. This structure implies a hierarchy, where the processor is the central decision maker and the producers form subsidiaries. It is important to point out that we focus on the producer and processor perspectives in this model. We touch on consumer surplus only indirectly via the output decisions under the different organizational arrangements. In this paper, we refer to organizational efficiency in terms of aggregate output and aggregate profits of the different organizational arrangements under given parameter constellations.

The chronological order of events in the model is as follows. At the first stage, the agents decide at how much generalizable and non-generalizable knowledge to acquire in order to adapt their decisions regarding output levels and pricing. At the second stage, production takes place, and each producer chooses the quantity that maximizes the producer's objective function. At the third stage, the price at which the processor acquires the total amount of output from the producers is determined. The processor then processes and markets the producers' output, and payoffs are realized at the processor



and the producer level.

### 3.1 Cooperative form of business organization

In this section, we analyze an organizational arrangement, in which all upstream producers align with each other in a cooperative. The suppliers of the downstream processor at the same time are the owners of the processor. Under such a cooperative structure, the producers themselves hold the residual rights to the processor's, i.e., the cooperative's, profits, and they receive these profits in the form of patronage returns. We consider a cooperative with two members, which can be considered as an identical number of two different member types, which are homogeneous within each type, but heterogeneous between types. Member types differ with regards to their marginal cost of production,  $c_i > 0$ , and patronage,  $\mu_i \in [0, 1]$ , with  $\mu_j = 1 - \mu_i$ . Member patronage determines the fraction  $\mu_i$  of the cooperative's profits that member  $i$  obtains. To impose more structure on individual member profits, we assume that if  $c_i > c_j$ , then  $\mu_i < \mu_j$ , which implies that the member with lower costs of production assumes higher patronage of the cooperative. That is, the low-cost member represents the "large" member in the cooperative.<sup>12</sup>

As it is the convention, we consider a setting in our model, where the members deliver their entire production to the cooperative, and the cooperative accepts each member's output.<sup>13</sup> We also consider delivery rights as non-tradable with outsiders. Investment decisions in the cooperative are taken on a one-member/one-vote basis, where a simple majority determines the vote outcome.<sup>14</sup>

According to these preliminaries and the components of the cooperative's objective function introduced in the preceding section, the profit function for the cooperative enterprise is

$$\pi^c = P(q_i + q_j) - C_{pm}(q_i, q_j) - C_\gamma(\gamma) - F, \quad (1)$$

where member  $i$ 's individual profit yields

$$\pi_i^c = \mu_i \pi^c - C_{p,i}(q_i, c_i, \gamma, \nu_i) - C_\nu(\nu_i), \quad (2)$$

with  $i \in \{1, 2\}$ . We define the parameters and variables in these profit functions as follows:  $P$  is the price at which member  $i$ 's output  $q_i \geq 0$  is sold on a competitive market. The function  $C_{pm}(q_i, q_j) \in C^1$  characterizes the cost of processing and marketing the cooperative's aggregate output  $Q = q_i + q_j$  and  $F > 0$  represents the associated sunk fixed costs. The function  $C_\gamma(\gamma) \in C^1$  represents the cost of acquiring generalizable knowledge which depends on the amount  $\gamma$  of generalizable knowledge implemented by the cooperative. Similarly,  $C_\nu(\nu_i) \in C^1$  is the cost function of acquiring non-generalizable knowledge which depends on amount  $\nu_i$  of non-generalizable knowledge that member  $i$  implements.  $C_{p,i}(q_i, c_i, \gamma, \nu_i) \in C^1$  is the production cost function of member  $i$ , where

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<sup>12</sup>This implies that members consider their patronage as exogenously given and that, with regard to their patronage, they consider their contribution to cooperative profits as negligible (Helmberger & Hoos 1962). This modeling approach also incorporates the possibility that members purchase shares based on projected output and then consider their patronage as fixed (Harris et al. 1996). In general, our approach embodies the assumption that the divergence in marginal costs affects patronage to the extent that lower production costs imply higher use of the cooperative enterprise.

<sup>13</sup>See Phillips (1953) and Helmberger & Hoos (1962) for seminal contributions to economic models of cooperatives and the underlying assumptions about the cooperative's governance.

<sup>14</sup>Via this mechanism, the influence of the median voter is decisive for the cooperative's decisions, see Hart & Moore (1996) for more on the influence of the median voter on the decisions in a cooperative.

$c_i > 0$  is a parameter that determines the marginal cost of production for member  $i$ .

It should be noted that by applying this modeling approach, we do not consider the cooperative as a single profit maximizing economic agent (as in Helmberger & Hoos 1962), but as a patron-owned utility-enterprise to supplement the patrons' independent ventures (as in Trifon 1961). To make our model tractable, we impose the following assumptions that hold throughout the paper:

**A1.** Marginal knowledge acquisition costs are linear with  $\partial C_\gamma(\gamma)/\partial\gamma = \gamma$  and  $\partial C_\nu(\nu)/\partial\nu = \nu$ .

**A2.** The cost of production is given by  $C_p(q, c, \gamma, \nu) = \frac{c}{2}f(\gamma, \nu)q^2$ , where  $f(\gamma, \nu) \in C^1$  is a cost-reducing function with  $\partial f(\gamma, \nu)/\partial\gamma = f_\gamma(\gamma, \nu) < 0$ , and  $\partial f(\gamma, \nu)/\partial\nu = f_\nu(\gamma, \nu) < 0$ .

**A3.** Marginal processing and marketing costs are constant with  $\partial C_{pm}(q_i, q_j)/\partial q_i = r$ .<sup>15</sup>

**A4.** We consider a setting, where we can analyze the influence of generalizable and non-generalizable knowledge on production costs separately. We therefore assume that  $f(\gamma, \nu)$  has the following properties:<sup>16</sup>

$$\frac{f_\gamma(\gamma, \nu)}{f(\gamma, \nu)^2} = -a \text{ and } \frac{f_\nu(\gamma, \nu)}{f(\gamma, \nu)^2} = -(1 - a).$$

The parameter  $a \in [0, 1]$  in A4 can be interpreted as a measure for the relative importance of generalizable knowledge in the production function. That is, a higher  $a$  implies that the cost-reducing effect of generalizable knowledge on production costs increases. At the same time, the relative importance of non-generalizable knowledge decreases, i.e., the effect of a higher  $\nu_i$  on production costs is smaller.

To determine the members' decisions in the cooperative, we first have to take a look at the transaction between the cooperative and its members. As the full profits of the cooperative go to the members according to their patronage, the problem at Stage 3, i.e., the transaction between the cooperative and its members, directly translates into the individual members' production decisions at Stage 2. Member  $i \in \{1, 2\}$  of the cooperative chooses its output  $q_i$  to maximize its individual profit and thus solves the maximization problem  $\max_{q_i \geq 0} \pi_i^c$  at Stage 2. We derive the following first-order condition, which implicitly defines the production decision by member  $i$ :<sup>17</sup>

$$\frac{\partial \pi_i^c}{\partial q_i} = \mu_i \left( P - \frac{\partial C_{pm}(q_i^c, q_j^c)}{\partial q_i} \right) - \frac{\partial C_{p,i}(q_i^c, c_i, \gamma, \nu_i)}{\partial q_i}. \quad (3)$$

**Lemma 1** *Under A1-A3, the optimal (anticipated) level of production of member  $i$  for Stage 2 in the cooperative is given by*

$$q_i^c(\gamma, \nu_i) = \frac{\mu_i(P - r)}{c_i f(\gamma, \nu_i)}. \quad (4)$$

**Proof.** Straightforward by noting that under A1-A3, the first-order condition is given by  $\frac{\partial \pi_i^c}{\partial q_i} = \mu_i(P - r) - c_i f(\gamma, \nu_i)q_i^c = 0$ . ■

<sup>15</sup>To guarantee non-negative profits, we assume that  $P - r > 0$ .

<sup>16</sup>This assumption allows us to draw conclusions for a broad set of functional forms for  $f(\gamma, \nu)$  and enables us to compare outcomes among different organizational arrangements. For example, this property is fulfilled for  $f(\gamma, \nu) = (a\gamma + (1 - a)\nu)^{-1}$ .

<sup>17</sup>It can be easily verified that the second-order conditions for a maximum are satisfied.

We derive that the anticipated level of production,  $q_i^c(\gamma, \nu_i)$ , increases with a higher investment level in both types of knowledge. These results follow from the decreasing effect of knowledge on production costs, which induces members to increase their output. Moreover, we find that increasing member  $i$ 's share  $\mu_i$  of the cooperative profit increases the anticipated level of production  $q_i^c(\gamma, \nu_i)$ , which is due to the higher fraction of marginal profits that member  $i$  obtains.

In a next step, we distinguish the members' optimal decision about acquiring knowledge at Stage 1 according to the two types of knowledge that we examine, generalizable and non-generalizable knowledge. At Stage 1, member  $i$  chooses the optimal acquisition level of generalizable and non-generalizable knowledge to maximize its profits.

**Non-generalizable knowledge:** Plugging the anticipated level of production,  $q_i^c(\gamma, \nu_i)$ , into the profit function  $\pi_i^c$ , yields the maximization problem  $\max_{\nu_i \geq 0} \pi_i^c(q_i^c, q_j^c)$  for member  $i$  at Stage 1. The first-order condition for member  $i$  is then given by<sup>18</sup>

$$\frac{\partial \pi_i^c}{\partial \nu_i} = \mu_i \left( P - \frac{\partial C_{pm}}{\partial q_i^c} \right) \frac{\partial q_i^c}{\partial \nu_i} - \left( \frac{\partial C_{p,i}}{\partial q_i^c} \frac{\partial q_i^c}{\partial \nu_i} + \frac{\partial C_{p,i}}{\partial \nu_i} \right) - \frac{\partial C_\nu}{\partial \nu_i} = 0 \quad (5)$$

and implicitly defines member  $i$ 's optimal acquisition level  $\nu_i^c$  of non-generalizable knowledge. We identify the following effects on the first-order condition of an increase in the acquisition of non-generalizable knowledge:

(i) The *profit effect* is given by  $\mu_i(P - \frac{\partial C_{pm}}{\partial q_i^c}) \frac{\partial q_i^c}{\partial \nu_i}$ : i.e., a higher  $\nu_i^c$  implies higher anticipated output  $q_i^c$ , which increases processing and marketing costs. At the same time, it also increases revenues. Since  $P - \frac{\partial C_{pm}}{\partial q_i^c} \stackrel{A3}{=} P - r > 0$ , revenues increase more than costs such that profits of the cooperative will increase, yielding a positive sign for the profit effect.

(ii) The *production cost effect* is given by  $\frac{\partial C_{p,i}}{\partial q_i^c} \frac{\partial q_i^c}{\partial \nu_i} + \frac{\partial C_{p,i}}{\partial \nu_i}$  and is composed of two different effects: (a) The indirect production cost effect is given by  $\frac{\partial C_{p,i}}{\partial q_i^c} \frac{\partial q_i^c}{\partial \nu_i} > 0$ : i.e., a higher  $\nu_i^c$  implies higher anticipated output  $q_i^c$ , which increases production costs and therefore has a negative effect on the first-order condition (5). (b) The direct production cost effect is given by  $\frac{\partial C_{p,i}}{\partial \nu_i} < 0$ : i.e., a higher  $\nu_i^c$  implies lower production costs for each level of anticipated output  $q_i^c$  which has a positive effect on the first-order condition (5). Under A1-A4, the indirect dominates the direct production cost effect such that overall production costs increase through a higher investment level in non-generalizable knowledge.

(iii) The *knowledge cost effect* is given by  $\frac{\partial C_\nu}{\partial \nu_i} > 0$  and describes the fact that investments in non-generalizable knowledge are costly.

It is important to mention that member  $i$  does not receive the full marginal return from a higher investment level  $\nu_i^c$  in non-generalizable knowledge because it obtains only share  $\mu_i$  of the cooperative's profits. On the other hand, it must bear the full investment costs in this type of knowledge and the knowledge-induced higher production costs.

**Generalizable knowledge:** Regarding the acquisition of generalizable knowledge, it should be noted that member  $i$  chooses its individually optimal acquisition level  $\gamma_i$  to maximize its profits.<sup>19</sup> Plugging the anticipated level of production  $q_i^c(\gamma, \nu_i)$  into the

<sup>18</sup>Note that  $q_j^c$  does not depend on  $\nu_i$ .

<sup>19</sup>Because the two members are asymmetric with respect to their costs, they want to acquire different levels of generalizable knowledge, i.e.,  $\gamma_i \neq \gamma_j$ . We assume that the cooperative then implements, based

profit function  $\pi_i^c$  yields the maximization problem  $\max_{\gamma \geq 0} \pi_i^c(q_i^c, q_j^c)$  for member  $i$  in Stage 1. By noting that  $q_j^c$  depends on  $\gamma$ , the first-order condition for member  $i$  is then given by<sup>20</sup>

$$\frac{\partial \pi_i^c}{\partial \gamma} = \mu_i \left[ \left( P - \frac{\partial C_{pm}}{\partial Q^c} \right) \frac{\partial (q_i^c + q_j^c)}{\partial \gamma} - \frac{\partial C_\gamma}{\partial \gamma} \right] - \left( \frac{\partial C_{p,i}}{\partial q_i^c} \frac{\partial q_i^c}{\partial \gamma} + \frac{\partial C_{p,i}}{\partial \gamma} \right) = 0 \quad (6)$$

and implicitly defines member  $i$ 's optimal acquisition level  $\gamma_i^c$  of generalizable knowledge. Similar to non-generalizable knowledge, we identify the following effects on the first-order condition of an increase in the acquisition of generalizable knowledge:

(i) The *profit effect* is given by  $\mu_i \left[ \left( P - \frac{\partial C_{pm}}{\partial Q^c} \right) \frac{\partial (q_i^c + q_j^c)}{\partial \gamma} \right] > 0$ : i.e., a higher  $\gamma$  implies higher own anticipated output  $q_i^c$ , but also higher anticipated output  $q_j^c$  of the other member  $j$ . Contrary to above, member  $i$  takes into account the impact of its behavior on the other member's output.

(ii) The *knowledge cost effect* is given by  $\mu_i \frac{\partial C_\gamma}{\partial \gamma} > 0$ . Compared to the investment costs in non-generalizable knowledge, however, member  $i$  only bears the fraction  $\mu_i$  of the investment costs in generalizable knowledge and, because of that, these costs appear only once in the cooperative.

(iii) The *production cost effect* is given by  $\frac{\partial C_{p,i}}{\partial q_i^c} \frac{\partial q_i^c}{\partial \gamma} + \frac{\partial C_{p,i}}{\partial \gamma}$  and is similar to above because member  $i$  does not take the effect on the other members' production costs into account. As above, there is an indirect production cost effect because the increase in generalizable knowledge leads to an increase in output and thus increases production costs. There is also a direct production cost effect, however, which incorporates the reduction in production cost via an increase in generalizable knowledge.

From (5) and (6), we derive the following results.

**Lemma 2** *Under A1-A4, the Stage 1 equilibrium levels for knowledge acquisition of member  $i$  are given by:*

$$\nu_i^c = \frac{1 - a}{c_i} \frac{\mu_i^2 (P - r)^2}{2} \quad \text{and} \quad \gamma_i^c = a \left( \frac{\mu_i}{c_i} + \frac{2\mu_j}{c_j} \right) \frac{(P - r)^2}{2},$$

with  $i, j \in \{1, 2\}$  and  $i \neq j$ .

**Proof.** See Appendix A.1. ■

We derive from this lemma that the large member acquires more non-generalizable and less generalizable knowledge than the small member. The reason for this difference stems from the nature of generalizable and non-generalizable knowledge, and the cooperative's nature of allocating its profits according to patronage. The members of the cooperative bear the costs of acquiring non-generalizable knowledge individually. This implies that a member that receives a larger share in the cooperative's profits will also acquire more non-generalizable knowledge, because, via the higher patronage returns, this type of knowledge is more profitable for the large member.

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on a simple majority mechanism, the corresponding knowledge level.

<sup>20</sup>Recall that member  $i$  is not able to observe the other member  $j$ 's acquisition level  $\gamma_j$ . For tractability, we therefore assume that member  $i$ 's preferred acquisition level for generalizable knowledge,  $\gamma_i$ , does not influence member  $j$ 's preferred acquisition level  $\gamma_j$ . Hence, member  $i$  does not include  $\gamma_j$  in its optimization problem. For the joint acquisition decision of the cooperative, we assume that members reveal their true preferences regarding their optimum level of generalizable knowledge when the cooperative's members take a collective decision.

In contrast, members share the cost of generalizable knowledge according to their patronage, because they not only receive the cooperative's revenues according to patronage, but also its costs.<sup>21</sup> The small member bears a relatively smaller share of the cost of generalizable knowledge than the large member. However, generalizable knowledge directly, and not via patronage, reduces the costs of production of all members. In summary, this leads to relatively stronger incentives for the small member to acquire generalizable knowledge than for the large member. These incentives for the small member to acquire generalizable knowledge increase with a higher cost heterogeneity between members yielding a higher difference in the levels of generalizable knowledge.<sup>22</sup> A larger cost heterogeneity implies lower relative output of the small member, implying lower production costs, but at the same time, it can benefit from the cooperative's profit. In the extreme, the small member would have zero output and therefore no costs of production but would still realize a positive profit.

Next, we analyze which level of generalizable knowledge will be implemented in the cooperative. Remember that all decisions about the cooperative's investments are taken according to a one-member/one-vote, simple majority mechanism. For our setup, this implies that the cooperative's level of acquiring generalizable knowledge is given by

$$\gamma^c = \frac{1}{2}(\gamma_1^c + \gamma_2^c) = \frac{3a}{4} \left( \frac{\mu_1}{c_1} + \frac{\mu_2}{c_2} \right) (P - r)^2,$$

which indicates that the cooperative's collective level of acquiring generalizable knowledge is the mean of the sum of the individually optimal levels of knowledge, following the outcome of the median-vote (Roberts 1977, Hart & Moore 1996).<sup>23</sup>

Substituting the equilibrium acquisition levels of knowledge into (4), yields equilibrium output of member  $i$  in the cooperative as  $\hat{q}_i^c = \frac{\mu_i(P-r)}{c_i f(\gamma^c, \nu_i^c)}$ . Similarly, we obtain aggregate profits of the members organized in a cooperative of  $\Pi^c = \pi_i^c + \pi_j^c - C_{pm} - C_\gamma - F$ .

To derive the comparative statics of knowledge acquisition with respect to  $\mu_i$ , we assume without loss of generality that member 1 has lower marginal production costs than member 2, i.e.,  $c_1 < c_2$  and therefore  $\mu_1 > \mu_2 = 1 - \mu_1$  holds.

**Lemma 3** (i) *Regarding non-generalizable knowledge, we derive:  $\frac{\partial \nu_1^c}{\partial \mu_1} > 0$ ,  $\frac{\partial \nu_2^c}{\partial \mu_1} < 0$  and  $\frac{\partial(\nu_1^c + \nu_2^c)}{\partial \mu_1} > 0$ .*

(ii) *Regarding generalizable knowledge, we derive:  $\frac{\partial \gamma_1^c}{\partial \mu_1} < 0 \Leftrightarrow c_2 \in (c_1, 2c_1)$ ,  $\frac{\partial \gamma_2^c}{\partial \mu_2} < 0$  and  $\frac{\partial \gamma^c}{\partial \mu_1} > 0$ ,  $\frac{\partial \gamma^c}{\partial \mu_2} < 0$ .*

Regarding part (i), it is straightforward to see that increasing member 1's share of the cooperative's profit induces this member to increase its acquisition level  $\nu_1^c$  of non-generalizable knowledge, because marginal revenue increases. Simultaneously, incentives for the other member, 2, decrease. The increase compensates for the decrease such that aggregate acquisition level  $\nu_1^c + \nu_2^c$  increases.

<sup>21</sup>Note that the investment level  $\gamma_i^c$  in generalizable knowledge of member  $i$  depends on the other member's cost structure.

<sup>22</sup>The heterogeneity between members in terms of costs is larger, the higher are marginal costs  $c_j$  of the small member and/or the lower are marginal costs  $c_i$  of the large member.

<sup>23</sup>We consider the cooperative's decision over collective investments as binding for the members, i.e., once the members have held a vote about a particular investment, all members adhere to the outcome of the vote.

Part (ii) shows that the large member, 1, wants to acquire more generalizable knowledge if its share of the cooperative's profits increases, but only if both members are sufficiently unequal in terms of their cost structure, i.e.,  $\frac{\partial \gamma_1^c}{\partial \mu_1} > 0 \Leftrightarrow c_2 > 2c_1$ . Otherwise, the larger member's incentive to acquire generalizable knowledge decreases, i.e.,  $\frac{\partial \gamma_1^c}{\partial \mu_1} < 0 \Leftrightarrow c_2 \in (c_1, 2c_1)$ . The intuition behind this result is as follows. An increase in the share  $\mu_1$  of member 1 has two effects on its first-order condition. First, it has a direct positive effect by increasing marginal profits. Second, it has an indirect negative effect through a lower anticipated output  $q_2^c$  of member 2. To increase  $\mu_1$  entails a decrease of member 2's share  $\mu_2$  of the cooperative profit, which induces a decrease in  $q_2^c$  (see Lemma 1). A lower  $q_2^c$ , in turn, negatively affects aggregate anticipated output, which lowers marginal profit of member 1. This negative effect on member 1's marginal profit decreases with a higher heterogeneity between members in terms of costs because member 2's anticipated output  $q_2^c$  is a decreasing function in  $c_2$ .<sup>24</sup>

Particularly, if  $c_2 > 2c_1$ , then the positive effect on member 1's first-order condition dominates the negative effect, and member 1 will increase  $\gamma_1^c$  if its share  $\mu_1$  increases. The opposite is true in the case that  $c_2 < 2c_1$ . The impact of the negative effect is comparatively stronger than the positive effect, because a one-unit increase in  $c_i$  has a weaker effect on  $\gamma_i^c$  than a one-unit increase in  $c_j$ , everything else being equal. This result holds because higher marginal costs  $c_i$  mitigate the production cost effect in member  $i$ 's first-order condition, but they do not affect the production cost effect in member  $j$ 's first-order condition.

Interestingly, independent of the cost structure, the small member 2 always wants to acquire less generalizable knowledge if its share  $\mu_2 = 1 - \mu_1$  of the cooperative's profits increases (which is the case when  $\mu_1$  decreases), i.e.,  $\frac{\partial \gamma_2^c}{\partial \mu_2} < 0$ . For the small member, the negative effect always dominates the positive effect because  $c_2 > c_1$ .

As mentioned above, the cooperative will acquire  $\gamma^c = \frac{1}{2}(\gamma_1^c + \gamma_2^c)$  units of generalizable knowledge. We find that increasing the share  $\mu_1$  of the large member always induces the cooperative to spend more on generalizable knowledge, while the opposite is true regarding the share  $\mu_2$  of the small member. Formally,  $\frac{\partial \gamma^c}{\partial \mu_1} > 0$  and  $\frac{\partial \gamma^c}{\partial \mu_2} < 0$  iff  $c_2 > c_1$ . That is, even if the large member wants to decrease  $\gamma_1^c$  as a reaction to a higher  $\mu_1$  (in case of  $c_2 \in (c_1, 2c_1)$ ), this decrease is always compensated for by the increase in  $\gamma_2^c$  of the small member such that  $\gamma^c$  increases.

### 3.2 Market form of business organization

In this section, we consider the market form of business organization. We characterize the market form as an arrangement, where each producer is organized as an independent firm that maximizes its profits individually. One important characteristic of this organizational arrangement is the non-existence of coordination among single firms. The producers interact with the processor and transact their output individually. Additionally, producers do not share common costs. We set up the model of this vertically separated organizational form by including a price for the product, at which each producer sells to the processor. We assume that the processor can rule out the option of side-trading among the producers. As introduced above, we model a monopsony processor, where the processor exercises market power vis-a-vis the producers via the price for the output that it pays to the producers. Market power on the side of the processor results in a price  $P_i^m$ , for which holds that  $P_i^m < P$ .

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<sup>24</sup>The heterogeneity between members in terms of costs is larger, the higher  $c_2$  and/or the lower is  $c_1$ .

The profit function of the processor in the market form of business organization is given by

$$\pi^m = (P - P_i^m)q_i + (P - P_j^m)q_j - C_{pm}(q_i, q_j) - F, \quad (7)$$

where  $P_i^m$  represents the price, at which producer  $i \in \{1, 2\}$  sells  $q_i$  to the processor. We consider the fixed costs of processing and marketing as sunk, resembling, for example, planning and set-up costs for the transaction between the processor and each producer  $i$ . These costs enter the processor's profit as well as its threat point in the bargaining process.

The profit function of producer  $i$  is given by

$$\pi_i^m = P_i^m q_i - C_{p,i}(q_i, c_i, \gamma_i, \nu_i) - C_\gamma(\gamma_i) - C_\nu(\nu_i). \quad (8)$$

At Stage 3, the processor and the individual producers bargain over the price  $P_i^m$ , at which producer  $i$  sells its output to the processor.<sup>25</sup> We assume that the processor and producer  $i$  bargain in bilateral Nash-bargaining fashion over price  $P_i^m$  (e.g., Nash 1950, Binmore et al. 1986). The underlying optimization problem then is

$$\tilde{P}_i^m(q_i) = \arg \max_{P_i^m \geq 0} \{(\pi_i^m - t_i)^\rho (\hat{\pi}_i^m - T_i)^{1-\rho}\},$$

where  $\rho \in (0, 1)$  is producer  $i$ 's level of bargaining power and  $(t_i, T_i) = (0, -F_i)$  stand for the threat points of producer  $i$  and the processor, respectively, in case the bargaining does not result in an exchange.<sup>26</sup> In the case that there is no exchange between the processor and producer  $i$ , the producer makes zero profit, i.e.,  $t_i = 0$  and the processor has to bear the sunk fixed costs  $F_i$ , i.e.,  $T_i = -F_i$ . The processor's profit realized with producer  $i$  is given by  $\hat{\pi}_i^m = (P - P_i^m)q_i - C_{pm}(q_i) - F_i$ . We further assume that the producer and the processor have equal bargaining power, i.e.,  $\rho = 1/2$ .

By computing the first-order condition and solving for the optimal transfer price  $\tilde{P}_i^m$ , the solution to the above optimization problem is given as follows. For a given anticipated output  $q_i$ , the Nash bargaining solution for the transfer price is  $\tilde{P}_i^m(q_i) = 1/2 [P - C_{pm}(q_i)/q_i] + 1/2 [1/q_i (C_{p,i}(q_i, c_i, \gamma_i, \nu_i) + C_\gamma(\gamma_i) + C_\nu(\nu_i))]$ . Plugging  $\tilde{P}_i^m(q_i)$  into the profit function  $\pi_i^m$ , we derive producer  $i$ 's profit as

$$\pi_i^m = \frac{1}{2} [P x_i - C_{pm}(q_i) - C_{p,i}(q_i, c_i, \gamma_i, \nu_i) - C_\gamma(\gamma_i) - C_\nu(\nu_i)]. \quad (9)$$

The processor's profit stemming from its transaction with producer  $i$  equals producer  $i$ 's profit, except for the sunk fixed costs of processing and marketing that the processor has to bear because of its transaction with producer  $i$ .

At Stage 2, producer  $i$  solves the maximization problem  $\max_{q_i \geq 0} \pi_i^m$  where  $\pi_i^m$  is given

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<sup>25</sup>This bargaining process incorporates both the processor's as well as the individual producer's propensity to appropriate available rents. By threatening not to be willing to meet an agreement, each bargaining party can improve its bargaining power, to the extent where a failure of the bargaining process leads to no transaction. Note the resemblance of this bargaining situation to a hold-up problem, where the investment in generalizable and non-generalizable knowledge resembles non-redeemable costs and, apart from decreasing the cost of production of output  $q$ , does not have alternative use once undertaken (Klein et al. 1978, Gibbons 2005).

<sup>26</sup>We denote fixed costs of processing and marketing per producer  $i$  as  $F_i$ , with  $F_i + F_j = F$ .

by (9). As the related first-order conditions, we obtain<sup>27</sup>

$$\frac{\partial \pi_i^m}{\partial q_i} = \frac{1}{2} \left( P - \frac{\partial C_{pm}(q_i^m)}{\partial q_i} - \frac{\partial C_{p,i}(q_i^m, c_i, \gamma_i, \nu_i)}{\partial q_i} \right) = 0.$$

**Lemma 4** *Under A1-A3, the optimal (anticipated) level of production of producer  $i$  for Stage 2 in the market is given by*

$$q_i^m(\gamma_i, \nu_i) = \frac{(P - r)}{c_i f(\gamma_i, \nu_i)}. \quad (10)$$

**Proof.** Straightforward. ■

The optimal output level of a producer in the market form of business organization is characterized by the price on the competitive market, the marginal costs of processing and marketing, as well as the cost of production of  $q$ . As opposed to the patronage-based profit-allocation in the cooperative, producers in the market can appropriate the full profit that they generate in exchange with the processor, up to the extent determined by the bargaining outcome. The processor and the producers bargain over the transfer price  $P^m$ , which leads to the cost of processing and marketing directly influencing producer output. Additionally it has to be noted that producers independently acquire generalizable and non-generalizable knowledge, which yields a direct effect of the individually acquired knowledge on output.

At Stage 1, the producers decide over how much generalizable and non-generalizable knowledge to acquire. Plugging  $q_i^m(\gamma_i, \nu_i)$  into the profit function  $\pi_i^m$  yields the maximization problem  $\max_{(\gamma_i, \nu_i) \geq 0} \pi_i^m(q_i^m, q_j^m)$  for each producer  $i$ . The corresponding first-order conditions are given by

$$\frac{\partial \pi_i^m}{\partial \kappa_i} = \frac{1}{2} \left[ \left( P - \frac{\partial C_{pm}}{\partial q_i^m} \right) \frac{\partial q_i^m}{\partial \kappa_i} - \left( \frac{\partial C_{p,i}}{\partial q_i^m} \frac{\partial q_i^m}{\partial \kappa_i} + \frac{\partial C_{p,i}}{\partial \kappa_i} \right) - \frac{\partial C_{\kappa_i}}{\partial \kappa_i} \right] = 0, \quad (11)$$

where  $\kappa_i \in \{\gamma_i, \nu_i\}$ .

When we compare these first-order conditions with Equations (5) and (6), we observe that the profit effect in the market form of organization,  $(P - \frac{\partial C_{pm}}{\partial q_i^m}) \frac{\partial q_i^m}{\partial \kappa_i} > 0$ , incorporates that producer  $i$  obtains the full return on its transaction with the processor, based on the price  $\tilde{P}_i^m$ , and not a share of the processor's profits, as is the case in the cooperative. The production cost effect with respect to generalizable knowledge, given by  $\frac{\partial C_{p,i}}{\partial q_i^m} \frac{\partial q_i^m}{\partial \gamma_i} + \frac{\partial C_{p,i}}{\partial \gamma_i}$ , only depends on individual knowledge acquisition, and analogous to the knowledge cost effect,  $\mu_i \frac{\partial C_{\kappa_i}}{\partial \gamma_i} > 0$  denotes that, contrary to the case of the cooperative, there are no collective investments.

**Lemma 5** *Under A1-A4, the Stage 1 equilibrium levels for knowledge acquisition of producer  $i$  are given by:*

$$\nu_i^m = \frac{1 - a}{c_i} \frac{(P - r)^2}{2} \text{ and } \gamma_i^m = \frac{a}{c_i} \frac{(P - r)^2}{2}.$$

**Proof.** See Appendix A.2. ■

The outcomes for the Stage 1 equilibrium levels of knowledge acquisition of producer  $i$  are independent for the two producers, i.e., the producers' acquisition decisions do not

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<sup>27</sup>It can be easily verified that the second-order conditions for a maximum are satisfied.



influence each other. We also observe that the large producer will always acquire more generalizable and non-generalizable knowledge.

Substituting the equilibrium acquisition levels of knowledge into (10), yields equilibrium output of producer  $i$  in the market organization as  $\hat{q}_i^m(\gamma_i^m, \nu_i^m) = \frac{(P-r)}{c_i f(\gamma_i^m, \nu_i^m)}$ . Similarly, we obtain aggregate profits in the market form of organization, i.e., profits of the processor and the producers, of  $\Pi^m = \pi^m + \pi_1^m + \pi_2^m$ .

### 3.3 Hierarchical form of business organization

In this section we consider a setting, where the processor and the producers operate as a vertically integrated hierarchy. The producers form the processor's subsidiaries. In this hierarchical structure, the processor employs an agent to manage each separate production site. The processor (principal) then requires of each agent (producer) to produce a specific quantity of output  $s_i^h$ , based on the principal's profit maximization. After production is realized, the processor pays a salary  $w$  to the management of each subsidiary if its output equals the dictated quantity.

We assume that the processor receives all revenues and bears the observable costs generated by the producers. Thus, the salary  $w$  is the only return that each producer receives. The processor can observe the output of each producer and the production cost realized at each subsidiary, with the exception of the influence of generalizable and non-generalizable knowledge. In order to be able to judge the influence of the two different types of knowledge, it has to incur monitoring costs to ensure that the subsidiaries are acquiring and applying the relevant knowledge.<sup>28</sup> We integrate these monitoring costs as cost-increasing parameters  $\lambda_\gamma \geq 1$  and  $\lambda_\nu \geq 1$  in the cost functions of knowledge acquisition  $C_\gamma$  and  $C_\nu$  for generalizable and non-generalizable knowledge, respectively. We assume  $\partial C_\gamma(\gamma)/\partial \gamma = \lambda_\gamma \gamma$  and  $\partial C_\nu(\nu_i)/\partial \nu_i = \lambda_\nu \nu_i$  such that  $C_\gamma(\lambda_\gamma, \gamma) > C_\gamma(\gamma)$  and  $C_\nu(\lambda_\nu, \nu_i) > C_\nu(\nu_i)$ . Hence, for each level  $(\gamma, \nu_i)$ , the costs to acquire generalizable and non-generalizable knowledge are higher in the hierarchy than in the cooperative or the market form of business organization.

These cost differences arise because, initially, the principal cannot ensure that the subsidiaries acquire the relevant generalizable and non-generalizable knowledge. The contract between the principal and the agents managing the subsidiaries does not incorporate incentives for the agents to acquire knowledge beyond the level that the principal can observe and therefore control.<sup>29</sup> Thus, to control knowledge acquisition at the sub-

<sup>28</sup>By not monitoring the acquisition of knowledge, the processor would forgo potential profits, because the absence of knowledge would not allow the processor to control the producers output regarding its efficiency. See Jensen & Meckling (1995) for the necessity to monitor individuals with the relevant knowledge who also assume certain decision rights.

<sup>29</sup>As an alternative to the fixed salary contract, the processor could also delegate the decision about output to the subsidiaries and compensate the subsidiaries contingent on their output. In the case that the processor continues to bear all costs of production, this would yield attempts to appropriate rents on the side of the subsidiaries. As the processor cannot judge the costs of production beyond a certain degree due to the cost and influence of knowledge acquisition, the agent at the subsidiary could overreport costs and appropriate all expenses above actual costs (analogous to moral hazard, Fama 1980). Alternatively, the processor could delegate decision-rights and all costs to the subsidiary. This case shows a similar trade-off as the market form of business organization outlined above. The processor faces the trade-off that a higher output by the subsidiaries can only be bought at the expense of a higher salary to the subsidiaries. These two polar forms of compensation can also be combined by the processor: by installing a compensation practice that combines a fixed salary and a variable component, the processor can reduce its expenses on knowledge acquisition and set incentives for higher output, however, neither the need to

sidiaries, the principal has to engage in monitoring. The lack of a contract incentivizing knowledge acquisition and the resulting need for monitoring arise because any incentives to knowledge acquisition face the obstacle that the processor can neither observe the costs related to knowledge acquisition nor the impact of knowledge on costs. For the acquisition of non-generalizable knowledge, which has to be acquired for each subsidiary individually, this implies that the processor faces knowledge acquisition costs and monitoring costs for each subsidiary to be able to judge the influence of knowledge on the cost of production. By contrast, the processor can generalize the acquired generalizable knowledge across the subsidiaries, which implies that the hierarchy can acquire this type of knowledge once and allocate acquisition costs among all subsidiaries.

For the objective function of the hierarchy and its managers, i.e., the processor and the two producers, the hierarchical form of business organization implies the expression

$$\Pi^h = \pi_i^h + \pi_j^h - C_{pm}(q_i, q_j) - C_\gamma(\lambda_\gamma, \gamma) - F, \quad (12)$$

where the profit of subsidiary  $i$  is given by

$$\pi_i^h = Px_i - C_{p,i}(q_i, c_i, \gamma_i, \nu_i) - C_\nu(\lambda_\nu, \nu_i).$$

In our model of the vertically integrated hierarchy, the principal takes the centralized production decision. Note that the principal wants to maximize aggregate profits of the hierarchy, and consequently, under the given salary scheme, there is no transfer price at which the subsidiaries transfer their output to the processor. At Stage 2, the hierarchy thus chooses  $q_i$  by solving the maximization problem  $\max_{q_i \geq 0} \Pi^h$ , which yields the following first-order condition

$$\frac{\partial \Pi^h}{\partial q_i} = P - \frac{\partial C_{pm}(q_i^h)}{\partial q_i} - \frac{\partial C_{p,i}(q_i^h, c_i, \gamma, \nu_i)}{\partial q_i} = 0.$$

To determine the optimal output quantity  $q_i^h$  for subsidiary  $i$ , central management equalizes the marginal return of selling a unit to the competitive market with the marginal costs of production costs at each subsidiary and processing and marketing costs at the central processing plant. Note that, analogous to our model of the cooperative enterprise, the hierarchy determines optimal output per subsidiary with reference to the competitive price.

**Lemma 6** *Under A1-A3, the optimal (anticipated) level of production of subsidiary  $i$  for Stage 2 in the hierarchy is given by*

$$q_i^h(\gamma_i, \nu_i) = \frac{(P - r)}{c_i f(\gamma, \nu_i)}. \quad (13)$$

**Proof.** Straightforward. ■

Under the assumption of self-interest on the side of all agents, the cost of monitoring leads to an output decision by the processor that induces the producers to a lower level of knowledge acquisition than if they held property rights in the hierarchy's marginal profits. The salary payment to the subsidiaries does not incorporate any incentive effects to acquire knowledge beyond the level that is indicated by the processor. However, the

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acquire knowledge nor the restriction on optimum output as a consequence of a salary which yields a positive profit for the processor, can be fully eliminated.

cost of monitoring leads to less knowledge acquisition of each agent at the subsidiaries because the processor cannot judge and implement agents' knowledge acquisition without engaging in monitoring.

At Stage 1, where the processor induces the producers to acquire generalizable and non-generalizable knowledge, plugging  $q_i^h(\gamma, \nu_i)$  into profit function  $\Pi^h$  yields the following first-order conditions for the hierarchy's profit maximization problem:

$$\frac{\partial \Pi^h}{\partial \nu_i} = \left( P - \frac{\partial C_{pm}}{\partial q_i^h} \right) \frac{\partial q_i^h}{\partial \nu_i} - \left( \frac{\partial C_{p,i}}{\partial q_i^h} \frac{\partial q_i^h}{\partial \nu_i} + \frac{\partial C_{p,i}}{\partial \nu_i} \right) - \frac{\partial C_\nu}{\partial \nu_i} = 0 \quad (14)$$

$$\frac{\partial \Pi^h}{\partial \gamma} = \left( P - \frac{\partial C_{pm}}{\partial Q^h} \right) \left( \frac{\partial q_i^h}{\partial \gamma} + \frac{\partial q_j^h}{\partial \gamma} \right) - \frac{\partial C_\gamma}{\partial \gamma} - \frac{\partial \tilde{C}_p}{\partial \gamma} = 0 \quad (15)$$

with

$$\frac{\partial \tilde{C}_p}{\partial \gamma} = \left( \frac{\partial C_{p,i}}{\partial q_i^h} \frac{\partial q_i^h}{\partial \gamma} + \frac{\partial C_{p,i}}{\partial \gamma} \right) + \left( \frac{\partial C_{p,j}}{\partial q_j^h} \frac{\partial q_j^h}{\partial \gamma} + \frac{\partial C_{p,j}}{\partial \gamma} \right), \quad i, j \in \{1, 2\} \text{ and } i \neq j.$$

Comparing these first-order conditions with Equations (5) and (6), we observe that the profit effects with respect to generalizable and non-generalizable knowledge in the hierarchical form of organization, i.e.,  $(P - \frac{\partial C_{pm}}{\partial q_i^h}) \frac{\partial q_i^h}{\partial \nu_i}$  and  $(P - \frac{\partial C_{pm}}{\partial Q^h}) (\frac{\partial q_i^h}{\partial \gamma} + \frac{\partial q_j^h}{\partial \gamma})$ , do not show the influence of profit sharing according to patronage, as it takes place in the cooperative. The production cost effect with respect to generalizable knowledge, given by  $(\frac{\partial C_{p,i}}{\partial q_i^h} \frac{\partial q_i^h}{\partial \gamma} + \frac{\partial C_{p,i}}{\partial \gamma}) + (\frac{\partial C_{p,j}}{\partial q_j^h} \frac{\partial q_j^h}{\partial \gamma} + \frac{\partial C_{p,j}}{\partial \gamma})$ , incorporates that the hierarchy acquires generalizable knowledge only once for all subsidiaries, similar to collective acquisition of generalizable knowledge in the cooperative. An important difference between the first-order conditions of the hierarchy and the cooperative are the knowledge cost effects,  $\frac{\partial C_\nu}{\partial \nu_i}$  and  $\frac{\partial C_\gamma}{\partial \gamma}$ , because in case of the hierarchy, these effects incorporate the influence of monitoring costs  $\lambda_\gamma$  and  $\lambda_\nu$  on the marginal cost of acquiring generalizable and non-generalizable knowledge, respectively. These monitoring costs do not emerge in the cooperative.

**Lemma 7** *Under A1-A4, the Stage 1 equilibrium levels for knowledge acquisition are given by:*

$$\nu_i^h = \frac{1 - a}{c_i} \frac{(P - r)^2}{2\lambda_\nu} \text{ and } \gamma^h = a \left( \frac{1}{c_1} + \frac{1}{c_2} \right) \frac{(P - r)^2}{2\lambda_\gamma}.$$

**Proof.** See Appendix A.3. ■

As a consequence of the nature of generalizable knowledge, the hierarchy does not have to acquire generalizable knowledge for each subsidiary, but, similar to the cooperative, can distribute the costs of acquiring generalizable knowledge among the subsidiaries. For non-generalizable knowledge, this does not hold, as it is particular to each individual subsidiary. From Lemma 7, we can directly derive that the large, low-cost subsidiary acquires more non-generalizable knowledge than the small subsidiary. For generalizable knowledge, which is acquired jointly by the subsidiaries, we observe that lower marginal costs of production  $c_i$  lead to the hierarchy acquiring more generalizable knowledge. This influence of the cost of production on the amount of knowledge acquired stems from  $c_i$  functioning as a weighting factor of the influence of both knowledge types. Therefore, the smaller  $c_i$ , the stronger the influence of more generalizable and non-generalizable knowledge on subsidiary  $i$ 's cost of production.

The parameters  $\lambda_\gamma$  and  $\lambda_\nu$  yield important implications regarding the feasibility of monitoring knowledge acquisition. Different types of knowledge can entail different degrees of feasibility to monitor their acquisition and application (Birkinshaw et al. 2002). In the case that monitoring the knowledge acquisition at the subsidiaries becomes increasingly expensive for the hierarchy, we observe a decrease in knowledge acquired, up to an extent, where the hierarchy does not acquire any knowledge at all, i.e.,  $\lim_{\lambda_\gamma \rightarrow \infty} \gamma^h = 0$  and/or  $\lim_{\lambda_\nu \rightarrow \infty} \nu_i^h = 0$ .

Substituting the equilibrium acquisition levels of knowledge into (10), yields the demanded equilibrium output for subsidiary  $i$  in the hierarchy as  $\hat{q}_i^h(\gamma^h, \nu_i^h) = \frac{(P-r)}{c_{if}(\gamma^h, \nu_i^h)}$ . Similarly, we obtain the hierarchy's profits as  $\Pi^h = \pi_1^h + \pi_2^h - C_{pm} - C_\gamma - F$ .

## 4 Comparison of outcomes

In the next section, we compare the cooperative enterprise with the outcomes in the market and the hierarchical form of business organization. We compare the levels of knowledge acquisition in each organizational arrangement, as well as aggregate output and aggregate surplus. Recall that member 1 has lower marginal production costs than member 2, i.e.,  $c_1 < c_2$ . Consequently,  $\mu_1 > \mu_2 = 1 - \mu_1$  holds.

### 4.1 Comparison of knowledge acquisition outcomes

In this section, we compare the relative levels of generalizable and non-generalizable knowledge acquired in each organizational arrangement. We thereby distinguish between a comparison of the cooperative with the market form of business organization and a comparison of cooperatives with a centralized hierarchy. First, we compare the cooperative with the market and establish the following proposition.

**Proposition 1** *Under A1-A4, we derive the following results:*

(i) *Member  $i$  in the cooperative acquires less non-generalizable knowledge than producer  $i$  in the market, i.e.,  $\nu_i^c < \nu_i^m$ .*

(ii) *The cooperative always acquires more generalizable knowledge than the small producer in the market, i.e.,  $\gamma^c > \gamma_2^m$ , while this result is true with respect to the large producer, only if the large member in the cooperative receives a sufficiently large share of the cooperative's profits, i.e.,  $\gamma^c > \gamma_1^m \Leftrightarrow \mu_1 > \mu_1^*(c_1, c_2) \equiv \frac{2c_2 - 3c_1}{3(c_2 - c_1)}$ .*

**Proof.** See Appendix A.4. ■

The proposition shows that, compared to a cooperative, the market has an advantage in acquiring non-generalizable knowledge, but can have a disadvantage in acquiring generalizable knowledge.

To observe the intuition behind the result about non-generalizable knowledge in part (i), notice that increasing the investment level in this type of knowledge triggers a positive profit effect and a negative production cost effect in both organizational forms. Because member  $i$  only receives share  $\mu_i$  of the cooperative's profit, the anticipated output in Stage 1 is lower in the cooperative than in market, i.e.,  $q_i^c < q_i^m$ . It follows that the (positive) profit effect is stronger in the market than in the cooperative. At the same time, the (negative) production cost effect is also stronger in the market than in the cooperative. However, the profit effect is the dominant effect, i.e., the difference between the profit effects in the market and the cooperative always outweighs the difference between the

production cost effects such that producer  $i$  acquires more non-generalizable knowledge than member  $i$ , i.e.,  $\nu_i^m > \nu_i^c$ .

It immediately follows that aggregate costs to acquire non-generalizable knowledge are higher in the market than in the cooperative, i.e.,  $C_\nu^m = C_\nu(\nu_1^m) + C_\nu(\nu_2^m) > C_\nu^c = C_\nu(\nu_1^c) + C_\nu(\nu_2^c)$ . According to Lemma 3, in the cooperative the aggregate acquisition level  $\nu_1^c + \nu_2^c$  increases in  $\mu_1$  such that the difference  $C_\nu^m - C_\nu^c$  will decrease in  $\mu_1$ . Moreover, the difference  $C_\nu^m - C_\nu^c$  will also decrease in  $a$  because incentives to acquire non-generalizable knowledge decrease stronger in the market than in the cooperative if the relative importance  $a$  of generalizable knowledge increases, i.e.,  $\partial \nu_i^m / \partial a < \partial \nu_i^c / \partial a < 0$ .

Part (ii) shows that the cooperative always acquires more generalizable knowledge than the small producer in the market, while the cooperative acquires more generalizable knowledge than the large producer in the market but only if the large member's share  $\mu_1$  of cooperative's profit is above a threshold given by  $\mu_1^*$ . Similar to above, an increase in generalizable knowledge triggers a positive profit effect and a negative production cost effect. However in comparison to the market, member  $i$  in the cooperative takes into account that there is a positive effect of a higher level of generalizable knowledge on aggregate output. Additionally, member  $i$  only has to bear share  $\mu_i$  of these knowledge costs, while producer  $i$  incurs the full investment costs.

We find that the small member in the cooperative always wants to acquire more generalizable knowledge than either producer in the market, i.e.,  $\gamma_2^c > \gamma_i^m$ ,  $i \in \{1, 2\}$ . As explained in Section 3.1, the small member in the cooperative has strong incentives to acquire generalizable knowledge because it bears only a fraction of the corresponding investment costs but fully benefits from the knowledge-induced reduction in production costs.

Similarly, the large member in the cooperative acquires more generalizable knowledge than the small producer in the market, i.e.,  $\gamma_1^c > \gamma_2^m$ . However, it depends on the cost structure whether this result is true with respect to the large producer in the market. Particularly, only if the members in the cooperative are sufficiently equal in terms of their cost structure then the large member acquires more generalizable knowledge than the large producer, i.e.,  $\gamma_1^c > \gamma_1^m \Leftrightarrow c_2 \in (c_1, 2c_1)$ . Only in this case, member 1, who bears a higher share of the investment costs in  $\gamma$ , can sufficiently benefit from the higher (aggregate) output and the corresponding positive profit effect.

Recall that the cooperative acquires the mean of the individually optimal levels of generalizable knowledge, i.e.,  $\gamma^c = (1/2)(\gamma_1^c + \gamma_2^c)$ . Because  $\gamma_2^c > \gamma_1^c$  and  $\gamma_1^c > \gamma_2^m$ , we derive that  $\gamma^c > \gamma_2^m$ . If the members in the cooperative are sufficiently homogeneous, i.e.,  $c_2 \in (c_1, 2c_1)$ , then  $\gamma_1^c > \gamma_1^m$  and therefore  $\gamma^c > \gamma_1^m$ . Hence, only in the case of sufficiently heterogeneous members it depends on the share  $\mu_1$  that the large member receives from the cooperative's profit, whether or not the cooperative acquires more generalizable knowledge than the large producer. In particular,  $\mu_1$  must be above the threshold value  $\mu_1^*$  to guarantee that the cooperative acquires more generalizable knowledge than producer 1 in the market because  $\gamma_1^c$  increases in  $\mu_1$  if  $c_2 > 2c_1$  (see Lemma 3).<sup>30</sup>

We further derive that aggregate costs to acquire generalizable knowledge are higher in the cooperative than in the market if the large member's share of the cooperative profits is larger than another threshold  $\mu_1^{**} > \mu_1^*$ : i.e.,  $C_\gamma(\gamma^c) > C_\gamma(\gamma_1^m) + C_\gamma(\gamma_2^m) \Leftrightarrow$

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<sup>30</sup>Note that the threshold  $\mu_1^*$  is an increasing function in  $c_2$ , i.e., an increasing member heterogeneity implies that the critical share, which member 1 must receive, increases. If the members in the cooperative are sufficiently homogeneous, i.e.,  $c_2 \in (c_1, 3c_1)$ , then  $\mu_1^* < 1/2$  and hence  $\mu_1 > \mu_1^*$  is fulfilled for all feasible  $\mu_1 \in (1/2, 1)$ .

$$\mu_1 > \mu_1^{**} \equiv \frac{2c_2 - c_1}{3(c_2 - c_1)}.$$

In the next proposition, we compare the cooperative with the hierarchy.

**Proposition 2** *Under A1-A4, we derive the following results:*

(i) *Member  $i$  in the cooperative acquires more non-generalizable knowledge than subsidiary  $i$  in the hierarchy if the monitoring problem in the hierarchy with respect to non-generalizable knowledge is sufficiently large, i.e.,  $\nu_i^c > \nu_i^h \Leftrightarrow \lambda_\nu > \lambda_\nu^*(\mu_i) \equiv \frac{1}{\mu_i^2}$ .*

(ii) *The cooperative acquires more generalizable knowledge than the hierarchy if the monitoring problem in the hierarchy with respect to generalizable knowledge is sufficiently large, i.e.,  $\gamma^c > \gamma^h \Leftrightarrow \lambda_\gamma > \lambda_\gamma^*(\mu_1, c_1, c_2) \equiv \frac{2(c_1 + c_2)}{3(c_1\mu_2 + c_2\mu_1)}$ .*

**Proof.** See Appendix A.5. ■

The proposition shows that the cooperative has an advantage in acquiring knowledge as compared to the hierarchy if the monitoring problem in the hierarchy with respect to the corresponding type of knowledge is sufficiently large. According to part (i), the cooperative acquires more non-generalizable knowledge than the hierarchy if the monitoring problem is above a threshold given by  $\lambda_\nu^*(\mu_i)$ , which only depends on the share  $\mu_i$  of the cooperative's profit that member  $i$  obtains. The intuition for this result is as follows. Similar to above, acquiring more non-generalizable knowledge triggers a positive profit effect and a negative production cost effect for both member  $i$  in the cooperative and subsidiary  $i$  in the hierarchy. Whether the positive profit effect is stronger for member  $i$  than for subsidiary  $i$  depends on the relationship between member  $i$ 's share  $\mu_i$  of the cooperative's profits and the magnitude of the monitoring costs  $\lambda_\nu$  in the hierarchy. If  $\lambda_\nu > \lambda_\nu^*(\mu_i)$ , then the disincentives in the hierarchy due to the monitoring costs outweigh the disincentives in the cooperatives due to profit sharing. In this case, the profit effect is stronger in the cooperative than in the hierarchy.<sup>31</sup> As a result, member  $i$  acquires more non-generalizable knowledge than subsidiary  $i$  because the profit effect always dominates the production cost effect. Because the threshold value  $\lambda_\nu^*(\mu_i)$  is a decreasing function in  $\mu_i$  and therefore an increasing function in  $\mu_j = 1 - \mu_i$ , we derive the following result. If the spread in the share of the cooperative's profits increases, i.e.,  $\mu_1$  increases and  $\mu_2 = 1 - \mu_1$  decreases, the monitoring problem in the hierarchy can be weaker (must be larger) to guarantee that the large (small) member in the cooperative will acquire more non-generalizable knowledge than its counterpart in the hierarchy.

According to part (ii), the cooperative acquires more generalizable knowledge than the hierarchy if the monitoring problem in the hierarchy with respect to this type of knowledge is sufficiently large, i.e.,  $\lambda_\gamma > \lambda_\gamma^*(\mu_1, c_1, c_2)$ . This part of the proposition illustrates that when comparing the acquisition of generalizable knowledge in the cooperative with the hierarchy, two effects are critical: the difference of the members in the cooperative with respect to their patronage of the cooperative, and the cost for the processor in the hierarchy to monitor the subsidiaries' acquisition of generalizable knowledge. The intuition behind this result stems from the observation that with an increase in  $\mu_1$ , the large member wants to acquire more generalizable knowledge if the direct effect of an increasing  $\mu_1$  on the large member's profits, i.e., the impact of a greater share of the cooperative's profits, exceeds the indirect effect, i.e., the negative effect on the small

<sup>31</sup>Note the anticipated output is  $\mu_i$ -times lower for member  $i$  in the cooperative than for subsidiary  $i$  in the hierarchy, i.e.,  $q_i^c/q_i^h = \mu_i < 1$ , yielding a  $\mu_i$ -times lower marginal impact on member  $i$ 's anticipated output due to a one-unit increase in  $\nu_i$ .

member's output decision. As stated in Lemma 3, the direct effect is more likely to exceed the indirect effect if the heterogeneity regarding  $c_1$  and  $c_2$  among members is greater. At the same time, the small member always wants to acquire more generalizable knowledge when its share of the cooperative's profits decreases. For the cooperative enterprise as a whole, the consequences of an increase in  $\mu_1$  then entail part (ii) of the proposition.

If the members in the cooperative differ sufficiently in terms of their cost structure, and the large member in the cooperative receives a sufficiently large part of the cooperative's profit, then the claim of part (ii) of this proposition holds, even if the monitoring problem in the hierarchy does not exist.<sup>32</sup> In this case, the cooperative always acquires more knowledge than the hierarchy, because its profit sharing according to patronage induces both members to increase their acquisition of generalizable knowledge beyond the level that is acquired in the hierarchy.<sup>33</sup>

## 4.2 Comparison of output quantities and aggregate profits

In this section, we compare the equilibrium profits the producers obtain when they are organized as a cooperative enterprise with the equilibrium profits in the market form of business organization and the vertically integrated hierarchy. First, we compare the cooperative's profits with the aggregate outcome of producers and processor in the market. To make the comparison tractable, we henceforth assume that the cost-reducing function is given by  $f(\gamma, \nu) = (a\gamma + (1-a)\nu)^{-1}$  (A4').<sup>34</sup>

**Proposition 3** *Under A1-A4', aggregate profits are higher in the cooperative than in the market if the relative importance of generalizable knowledge is sufficiently high, i.e.,  $\Pi^c > \Pi^m \Leftrightarrow a > a_\pi^m(\mu_1, c_1, c_2)$ . Necessary conditions for this result to hold are:*

- (i) *members in the cooperative are sufficiently similar in terms of their cost structure, i.e.,  $\frac{c_2}{c_1} < c^m$ ,*
- (ii) *the member patronage of cooperative is sufficiently homogeneous, i.e.,  $\mu_1 \in (\underline{\mu}_1^m, \bar{\mu}_1^m)$ .*

**Proof.** See Appendix A.6. ■

The proposition shows that the cooperative can have an advantage over the market in terms of profits if the relative importance  $a$  of generalizable knowledge for the cost of production is sufficiently high. The higher  $a$ , the more the cooperative can capitalize on being able to collectively acquire generalizable knowledge. It is important to note that this only holds to the extent that the difference in cost structure and patronage between the members does not become too large. In the case that members are very unequal in terms of their cost structure, and/or the large member receives too large a share of the cooperative's profit, then aggregate profits in the market are higher than in the cooperative. The cooperative can only achieve higher profits than the actors in the market form of business organization if the cooperative's members can exploit their advantage in acquiring generalizable knowledge. This advantage is more pronounced for converging patronage levels between the large and the small member, in particular, when  $\mu_1 \in (\underline{\mu}_1^m, \bar{\mu}_1^m)$ , i.e., members receive a similar share in the cooperative's profits. The advantage is also more

<sup>32</sup>We can derive this from setting  $\lambda_\gamma = 1$  in part (ii) of the proposition, and obtaining a threshold value for  $\mu_1$  of  $\mu_1^* \geq \frac{2c_2 - c_1}{3(c_2 - c_1)}$ , above which the proposition holds independent of the monitoring problem in the hierarchy.

<sup>33</sup>Refer to Lemma 3 for the underlying mechanism.

<sup>34</sup>Note that this function satisfies A4.

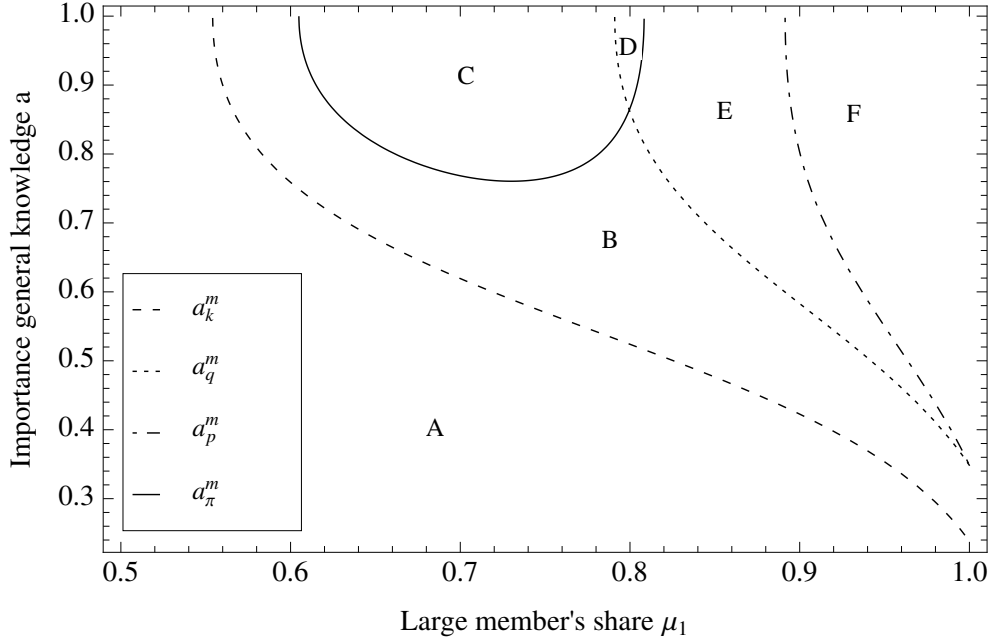


Figure 1: *Comparison of cooperative and market*

pronounced if the cost heterogeneity between member in the cooperative is small. From the cooperative's decision regarding the acquisition of generalizable knowledge, we know that more similar cost structures lead to more knowledge acquisition in the cooperative than in the market, which in turn enhances the cooperative's advantage.

To observe the intuition behind Proposition 3, we analyze the difference in profits  $\Delta\Pi = \Pi^c - \Pi^m$  between the cooperative and the market:

$$\Delta\Pi = (P - r)\Delta Q - \Delta C_p - \Delta C_k, \quad (16)$$

where  $\Delta Q = Q^c - Q^m$  is the difference in aggregate output,  $\Delta C_p = C_p^c - C_p^m$  is the difference in aggregate production costs, and  $\Delta C_k = (C_\gamma^c + C_\nu^c) - (C_\gamma^m + C_\nu^m)$  is the difference in knowledge costs for acquiring both types of knowledge. We establish some useful properties in the next lemma.

**Lemma 8** *Under A1-A4', the following inequalities are true:*

$\Delta Q > 0 \Leftrightarrow a > a_q^m(\mu_1, c_1, c_2)$ ,  $\Delta C_p > 0 \Leftrightarrow a > a_p^m(\mu_1, c_1, c_2)$  and  $\Delta C_k > 0 \Leftrightarrow a > a_k^m(\mu_1, c_1, c_2)$  with  $a_k^m < a_q^m < a_p^m$ .

**Proof.** See Appendix A.7. ■

The lemma shows that aggregate knowledge costs are larger in the cooperative than in the market if the relative importance of generalizable knowledge is sufficiently high, i.e.,  $a > a_k^m$ . Moreover, aggregate output is higher in the cooperative than in the market if the relative importance of generalizable knowledge is larger than another threshold  $a_q^m$ . Regarding aggregate production costs, it holds  $C_p^c > C_p^m \Leftrightarrow a > a_p^m$ .

We illustrate these thresholds for  $a$ , which are functions of  $\mu_1$ ,  $c_1$  and  $c_2$ , by fixing  $(c_1, c_2) = (0.1, 0.3)$  and varying  $\mu_1$  in Figure 1. The figure shows the ranges of  $(a, \mu_1)$ , for which the different components in (16) are positive or negative. To illustrate the specific thresholds and the related ranges, we consider the relative importance of generalizable



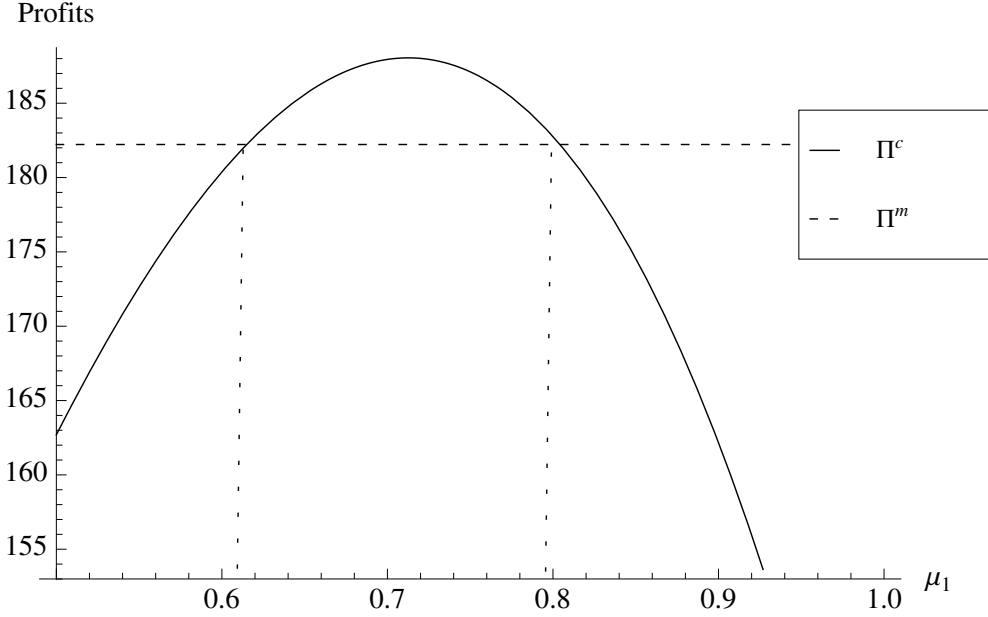


Figure 2: *Comparison of profits in cooperative and market*

knowledge as fixed at  $a = a' \equiv 0.9$ , and the large member's share  $\mu_1$  as varying, starting at  $\mu_1 = 0.5$ .

We consider the area  $A$ , representing the initial parameter constellation, where all components are lower in the cooperative than in the market. Augmenting  $\mu_1$  increases the aggregate acquisition level of non-generalizable and generalizable knowledge in the cooperative (Lemma 3), yielding higher knowledge costs but also a knowledge-induced reduction in production costs. At the same time, aggregate output increases, entailing higher aggregate production costs. If  $\mu_1$  is sufficiently large, i.e.,  $(a', \mu_1) \in B$ , then knowledge acquisition costs are higher, but output, production costs and profits are still lower in the cooperative than in the market. If  $\mu_1$  further increases, i.e.,  $\mu_1 \gtrapprox 0.62$  then  $(a', \mu_1) \in C$ . In this case, the knowledge-induced reduction in the production costs, in addition to the increase in output, imply higher profits in the cooperative (see Figure 2).<sup>35</sup> Note, however, that output and production costs are still lower in the cooperative. If  $(a', \mu_1) \in D$ , then output and profits are higher in the cooperative than in the market. By further increasing  $\mu_1$ , i.e.,  $\mu_1 \gtrapprox 0.8$  then  $(a', \mu_1) \in E$ . Now, we obtain that output is still higher in the cooperative, but acquisition costs for both types of knowledge are such that profits in the cooperative are lower than in the market (see Figure 2). Finally, if  $(a', \mu_1) \in F$ , then the knowledge-induced reduction in the production costs is so strong that the production costs in the cooperative are below the corresponding costs in the market. However, the lower production costs cannot compensate for the higher knowledge costs, such that profits are still lower in the cooperative compared to the market.

Next to the comparison of profits, Figure 1 also incorporates the relative output of cooperative and market. As Lemma 8 states, beyond a certain threshold for the importance of generalizable knowledge, namely  $a_q^m(\mu_1, c_1, c_2)$ , the cooperative generates a larger aggregate output than the market form of business organization. In Figure 2, the areas  $D$ ,  $E$ , and  $F$  indicate higher aggregate output of the cooperative than the market.

<sup>35</sup>In Figure 2, we set  $a = 0.9$ ,  $c_1 = 0.1$ ,  $c_2 = 0.3$ ,  $P = 7$ , and  $r = 5$ .

Next, we compare the cooperative's profits with the aggregate surplus of the hierarchy, where the producers function as subsidiaries to the processor. We state our results in the following proposition.

**Proposition 4** *Under A1-A4', aggregate profits are higher in the cooperative than in the hierarchy if the relative importance of non-generalizable knowledge is sufficiently high, i.e.,  $\Pi^c > \Pi^h \Leftrightarrow a < a_\pi^h(\mu_1, c_1, c_2)$ . Necessary conditions for this result to hold are:*

- (i) *the monitoring problem in the hierarchy exists, i.e.,  $\lambda_\gamma > 1$  and/or  $\lambda_\nu > 1$*
- (ii) *the large member in the cooperative receives a sufficiently large share of the cooperative's profit, i.e.,  $\mu_1 > \mu_1^h$ .*

**Proof.** See Appendix A.8. ■

From this proposition, we can derive that the cooperative obtains a competitive advantage over the hierarchy if non-generalizable knowledge has a sufficiently large influence on production costs. If the cost of monitoring exceeds the level defined in Proposition 2, the cooperative acquires more non-generalizable knowledge. Recall that a larger difference between members' patronage in the cooperative reduces the threshold for monitoring costs, above which the cooperative acquires more non-generalizable knowledge. This, next to the influence on the cooperative's higher acquisition of generalizable knowledge extends the cooperative's advantage regarding aggregate profits over the hierarchy. If, however, the hierarchy does not face monitoring costs, i.e.,  $\lambda_\gamma = 1$  and  $\lambda_\nu = 1$ , aggregate profits in the hierarchy are never below aggregate profits in the cooperative.

Similar to Proposition 3, we analyze the difference in profits  $\Delta\Pi = \Pi^c - \Pi^h$  between the cooperative and the hierarchy:

$$\Delta\Pi = (P - r)\Delta Q - \Delta C_p - \Delta C_k, \quad (17)$$

where  $\Delta Q = Q^c - Q^h$  is the difference in aggregate output,  $\Delta C_p = C_p^c - C_p^h$  is the difference in aggregate production costs, and  $\Delta C_k = (C_\gamma^c + C_\nu^c) - (C_\gamma^h + C_\nu^h)$  is the difference in knowledge costs for acquiring both types of knowledge. We establish the following lemma.

**Lemma 9** *Under A1-A4', the following inequalities are true:*

$\Delta Q > 0 \Leftrightarrow a < a_q^h(\mu_1, c_1, c_2)$ ,  $\Delta C_p > 0 \Leftrightarrow a < a_p^h(\mu_1, c_1, c_2)$  and  $\Delta C_k > 0 \Leftrightarrow a > a_k^h(\mu_1, c_1, c_2)$  with  $a_k^h < a_q^h < a_p^h$ .

**Proof.** See Appendix A.9. ■

Conversely to the comparison of cooperative and market form of business organization above, we find that aggregate output is higher in the cooperative than in the hierarchy if the relative importance of non-generalizable knowledge is sufficiently high, i.e.,  $a < a_q^h$ . Moreover, aggregate production costs are higher in the cooperative than in the hierarchy if the relative importance of non-generalizable knowledge is larger than another threshold, i.e.,  $a < a^q$ . Similarly to above, aggregate knowledge costs are higher in the cooperative than in the market if the relative importance of generalizable knowledge is sufficiently high, i.e.,  $a > a_k^h$ .

We illustrate these threshold parameters in Figure 3 for  $c_1 = 0.1$  and  $c_2 = 0.3$ . As for the case of comparing cooperative and market, the figure indicates ranges of  $(a, \mu_1)$  for which the different components of comparing the cooperative's and the hierarchy's profits in Equation (17) are positive or negative. To explain the different ranges, we consider the relative importance of non-generalizable knowledge as fixed at  $(1 - a) = (1 - a') \equiv 0.9$ , i.e.,

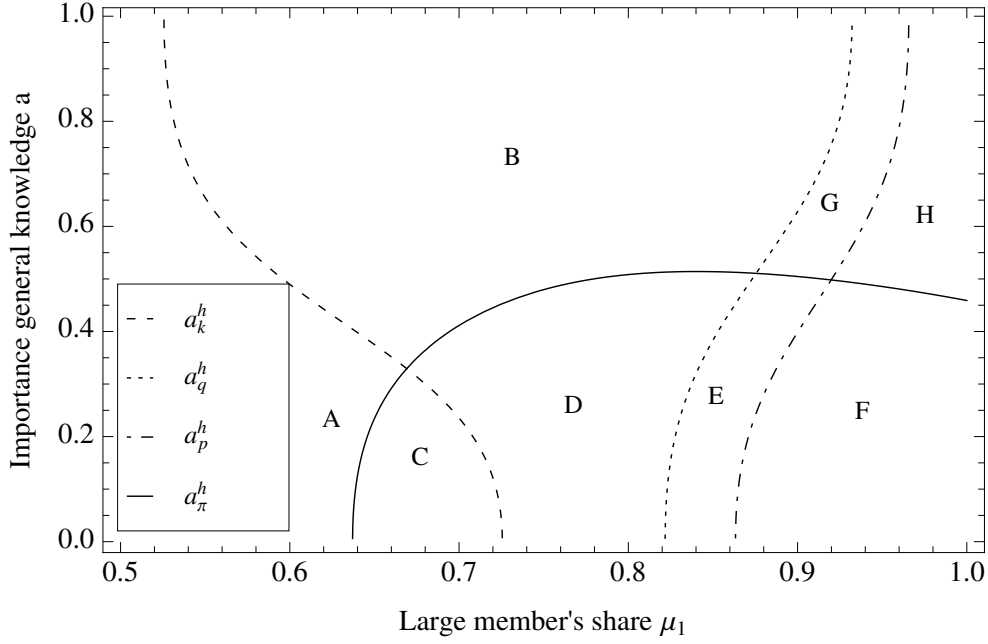


Figure 3: *Comparison of cooperative and hierarchy*

$a = 0.1$  and the large member's share  $\mu_1$  as varying, starting at  $\mu_1 = 0.5$ . This parameter constellation implies *A*, i.e., all components are lower in the cooperative than in the hierarchy, which we will use as a starting point for explaining Figure 3. As above, we continuously increase  $\mu_1$  and determine the sign of the different components of Equation (17), while holding  $a$  constant.<sup>36</sup> When, starting in *A*,  $\mu_1$  increases to an extent such that  $(a, \mu_1) \in C$ , we obtain a situation where the cooperative obtains higher aggregate profits than the hierarchy, but generates less output, bears lower costs of knowledge acquisition and lower costs of production. In the course of further increasing  $\mu_1$ , we arrive at area *D*, where the cooperative's profits and knowledge acquisition costs are higher than in the hierarchy, but its output and its cost of production are smaller. For a higher  $\mu_1$ , we then cross another threshold, after which the cooperative also generates more aggregate output than the hierarchy, i.e.,  $(a', \mu_1) \in E$ . As  $\mu_1$  further increases, and we observe a situation where  $(a, \mu_1) \in F$ , all components of Equation (17) become larger in the cooperative than in the hierarchy. For areas  $(a, \mu_1) \in B, G, H$ , the cooperative obtains smaller profits than the hierarchy despite higher costs of knowledge acquisition. In these areas, the cooperative's advantages as derived in Proposition 2 are absent for the lack of a sufficient level of importance of generalizable knowledge.

Analogous to Figure 1 for the comparison of the cooperative and the market, Figure 3 also incorporates the relative output of cooperative and hierarchy. As Lemma 9 states, beyond a certain threshold for the importance of generalizable knowledge, i.e.,  $a < a_q^h$ , the cooperative generates a larger aggregate output than the hierarchical form of business organization. In Figure 3, the areas *E*, *F*, *G*, and *H* indicate higher aggregate output of the cooperative than the market.

<sup>36</sup>As mentioned above, the threshold parameters for  $a$  are functions of  $\mu_1$ ,  $c_1$  and  $c_2$ . We hold  $a$ ,  $c_1$  and  $c_2$  constant and vary  $\mu_1$  for interpreting the different thresholds.

## 5 Conclusion

The cooperative enterprise is a very widespread form of business organization. Despite cooperatives' global influence and their presence in a large variety of sectors, research of cooperatives has not yet established a conclusive understanding of why cooperatives are competitive organizations in so many different fields. We contribute to research on the competitiveness of cooperatives by setting up a simple model of a cooperative and illustrating how advantages of the cooperative form of organizing emerge. A cooperative can provide an organizational structure for production and processing activities, which, compared to other organizational arrangements, namely the organization via a vertically separated market and a vertically integrated hierarchy, enhances knowledge acquisition, and enables higher output and higher total surplus.

From our model, we derive that the cooperative acquires less non-generalizable knowledge than the market, but more generalizable knowledge than the market if the large member in the cooperative receives a sufficiently large share of the cooperative's profits. Additionally, we derive that cooperatives generate higher output and larger aggregate profits than the market form of business organization if the influence of generalizable knowledge on production costs is large. In comparison to a centralized hierarchy, a cooperative acquires more generalizable and non-generalizable knowledge if the hierarchy faces monitoring costs regarding knowledge acquisition at the producer level. The cooperative produces more output and obtains higher total profits than the hierarchy in the case that non-generalizable knowledge is more important in the production process.

The proposed model intends to explain why cooperatives, despite some organizational peculiarities that can lead to reduced investment incentives, are such a widespread form of organizing transactions and frequently coexist with other forms of business organization. The model should pose a starting point for further analysis of the organizational peculiarities of cooperatives. For example, an extension of our model should provide more detailed analysis of the effect of the problems of vaguely defined property rights and the control problems frequently associated with cooperatives (Nilsson 1997). The influence of these problems has to be further assessed to obtain insights on what organizational attributes have to be adapted to address the problems, and what effects this generates for the competitive advantage of cooperatives.<sup>37</sup>

Our theoretical analysis of cooperatives can serve as a basis for empirical testing. For example, the importance of particular knowledge compared to generalizable knowledge should be determined for different sectors. Our theory predicts that sectors, in which non-generalizable knowledge is important in the production process, should display a stronger presence of cooperatives. In the case that empirical testing confirms our propositions, measures to foster the cooperative advantage and to mitigate the problems related to cooperatives should be established for the respective sectors.

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<sup>37</sup>See Chaddad & Cook (2004) for a typology of currently existing organizational designs of cooperatives

## A Appendix

### A.1 Proof of Lemma 2

First, we compute the Stage 1 equilibrium levels for non-generalizable knowledge acquisition. From the first-order conditions (5), we derive

$$\begin{aligned}\nu_i^c &= \mu_i (P - r) \frac{\mu_i (P - r) [-f_{\nu_i}(\gamma, \nu_i)]}{c_i f(\gamma, \nu_i)^2} \\ &\quad - \left[ \frac{\mu_i^2 (P - r)^2 [-f_{\nu_i}(\gamma, \nu_i)]}{c_i f(\gamma, \nu_i)^2} + \frac{c_i f_{\nu_i}(\gamma, \nu_i)}{2} \left( \frac{\mu_i (P - r)}{c_i f(\gamma, \nu_i)} \right)^2 \right] \\ &= \frac{[-f_{\nu_i}(\gamma, \nu_i)] \mu_i^2 (P - r)^2}{f(\gamma, \nu_i)^2 2c_i} = \frac{1 - a}{c_i} \frac{\mu_i^2 (P - r)^2}{2}\end{aligned}$$

Second, we compute the Stage 1 equilibrium levels for generalizable knowledge acquisition. From the first-order conditions (6), we derive

$$\begin{aligned}\gamma_i^c &= (P - r) \left( \frac{\mu_i (P - r) [-f_{\gamma}(\gamma, \nu_i)]}{c_i f(\gamma, \nu_i)^2} + \frac{\mu_j (P - r) [-f_{\gamma}(\gamma, \nu_j)]}{c_j f(\gamma, \nu_j)^2} \right) \\ &\quad - \frac{1}{\mu_i} \left[ \frac{\mu_i^2 (P - r)^2 [-f_{\gamma}(\gamma, \nu_i)]}{c_i f(\gamma, \nu_i)^2} + \frac{c_i f_{\gamma}(\gamma, \nu_i)}{2} \left( \frac{\mu_i (P - r)}{c_i f(\gamma, \nu_i)} \right)^2 \right] \\ &= -(P - r)^2 \left( \frac{\mu_i f_{\gamma}(\gamma, \nu_i)}{2c_i f(\gamma, \nu_i)^2} + \frac{\mu_j f_{\gamma}(\gamma, \nu_j)}{c_j f(\gamma, \nu_j)^2} \right) = a \left( \frac{\mu_i}{c_i} + \frac{2\mu_j}{c_j} \right) \frac{(P - r)^2}{2}\end{aligned}$$

It can be easily verified that the corresponding second-order conditions for a maximum are satisfied.

### A.2 Proof of Lemma 5

First, we compute the Stage 1 equilibrium levels for non-generalizable knowledge acquisition. From the first-order conditions (11), we derive

$$\nu_i^m = \left( P - \frac{\partial C_{pm}}{\partial q_i^m} \right) \frac{\partial q_i^m}{\partial \nu_i} - \left[ \frac{\partial C_{p,i}}{\partial q_i^m} \frac{\partial q_i^m}{\partial \nu_i} + \frac{\partial C_{p,i}}{\partial \nu_i} \right] = -\frac{(P - r)^2 f_{\nu_i}(\gamma_i, \nu_i)}{2c_i f(\gamma_i, \nu_i)^2} = \frac{1 - a}{c_i} \frac{(P - r)^2}{2}.$$

Second, we compute the Stage 1 equilibrium levels for generalizable knowledge acquisition. From the first-order conditions (11), we derive

$$\gamma_i^m = \left( P - \frac{\partial C_{pm}}{\partial q_i^m} \right) \frac{\partial q_i^m}{\partial \gamma_i} - \left( \frac{\partial C_{p,i}}{\partial q_i^m} \frac{\partial q_i^m}{\partial \gamma_i} + \frac{\partial C_{p,i}}{\partial \gamma_i} \right) = -\frac{(P - r)^2 f_{\gamma_i}(\gamma_i, \nu_i)}{2c_i f(\gamma_i, \nu_i)^2} = \frac{a}{c_i} \frac{(P - r)^2}{2}.$$

It can be easily verified that the corresponding second-order conditions for a maximum are satisfied.

### A.3 Proof of Lemma 7

First, we compute the Stage 1 equilibrium levels for non-generalizable knowledge acquisition. From the first-order conditions (14), we derive

$$\nu_i^h = \frac{1}{\lambda_\nu} \left[ \left( P - \frac{\partial C_{pm}}{\partial q_i^h} \right) \frac{\partial q_i^h}{\partial \nu_i} - \left( \frac{\partial C_{p,i}}{\partial q_i^h} \frac{\partial q_i^h}{\partial \nu_i} + \frac{\partial C_{p,i}}{\partial \nu_i} \right) \right] = -\frac{(P-r)^2 f_{\nu_i}(\gamma_i, \nu_i)}{2\lambda_\nu c_i f(\gamma_i, \nu_i)^2} = \frac{(P-r)^2 (1-a)}{2\lambda_\nu c_i}$$

Second, we compute the Stage 1 equilibrium levels for generalizable knowledge acquisition. From the first-order conditions (15), we derive

$$\begin{aligned} \gamma^h &= \frac{1}{\lambda_\gamma} \left[ \left( P - \frac{\partial C_{pm}}{\partial Q^h} \right) \frac{\partial (q_i^h + q_j^h)}{\partial \gamma} - \left( \frac{\partial C_{p,i}}{\partial q_i^h} \frac{\partial q_i^h}{\partial \gamma} + \frac{\partial C_{p,i}}{\partial \gamma} \right) - \left( \frac{\partial C_{p,j}}{\partial q_j^h} \frac{\partial q_j^h}{\partial \gamma} + \frac{\partial C_{p,j}}{\partial \gamma} \right) \right] \\ &= \frac{(P-r)^2}{2\lambda_\gamma} \left( \frac{-f_\gamma(\gamma, \nu_i)}{c_i f(\gamma, \nu_i)^2} + \frac{-f_\gamma(\gamma, \nu_j)}{c_j f(\gamma, \nu_j)^2} \right) = \frac{(P-r)^2}{2\lambda_\gamma} \left( \frac{a}{c_i} + \frac{a}{c_j} \right) \end{aligned}$$

It can be easily verified that the corresponding second-order conditions for a maximum are satisfied.

### A.4 Proof of Proposition 1

Part (i): Regarding non-generalizable knowledge, it is straightforward to show that  $\nu_i^c = \frac{1-a}{c_i} \frac{\mu_i^2 (P-r)^2}{2} < \nu_i^m = \frac{1-a}{c_i} \frac{(P-r)^2}{2}$  with  $\mu_i \in [0, 1]$ .

Part (ii): Regarding generalizable knowledge,  $\gamma^c > \gamma_2^m$  always holds, while  $\gamma^c > \gamma_1^m \Leftrightarrow \mu_1 > \frac{3c_1-2c_2}{3(c_1-c_2)}$ . The last inequality can only be fulfilled if producers are sufficiently heterogeneous with  $c_2 > \frac{3}{2}c_1$ . We further deduce  $\gamma_1^c > \gamma_1^m \Leftrightarrow c_2 \in (c_1, 2c_1)$  and  $\gamma_1^c > \gamma_2^m$ . Moreover, it holds  $\gamma_2^c > \gamma_i^m$ ,  $i \in \{1, 2\}$  always.

### A.5 Proof of Proposition 2

Part (i): Regarding non-generalizable knowledge, we derive

$$\nu_i^c = \frac{1-a}{c_i} \frac{\mu_i^2 (P-r)^2}{2} > \frac{1-a}{c_i} \frac{(P-r)^2}{2\lambda_\nu} = \nu_i^h \Leftrightarrow \lambda_\nu > \lambda_\nu^* \equiv \frac{1}{\mu_i^2}.$$

Part (ii): Regarding generalizable knowledge, we compute

$$\begin{aligned} \gamma^c &= \frac{3a}{4} \left( \frac{\mu_1}{c_1} + \frac{\mu_2}{c_2} \right) (P-r)^2 > a \left( \frac{1}{c_1} + \frac{1}{c_2} \right) \frac{(P-r)^2}{2\lambda_\gamma} = \gamma^h \\ &\Leftrightarrow \lambda_\gamma > \lambda_\gamma^* \equiv \frac{2(c_1+c_2)}{3[c_1\mu_2+c_2\mu_1]} \stackrel{\mu_2=1-\mu_1}{=} \frac{2(c_1+c_2)}{3[c_1+\mu_1(c_2-c_1)]}. \end{aligned}$$

## A.6 Proof of Proposition 3

Aggregate equilibrium profits in the cooperative are given by

$$\begin{aligned} \Pi^c = & \frac{(P-r)^2}{2} \left[ \frac{\mu_1(2+\mu_1)}{c_1 f(\gamma^c, \nu_1^c)} + \frac{\mu_2(2+\mu_2)}{c_2 f(\gamma^c, \nu_2^c)} \right] \\ & - \frac{(P-r)^4}{2} \left[ \frac{9a^2}{16} \left( \frac{c_2\mu_1 + c_1(1-\mu_1)}{c_1c_2} \right)^2 + \frac{(1-a)^2}{4} \left( \frac{c_2^2(\mu_1^2)^2 + c_1^2(\mu_2^2)^2}{c_1^2c_2^2} \right) \right] - F \quad (18) \end{aligned}$$

with  $f(\gamma^c, \nu_i^c) = (a\gamma^c + (1-a)\nu_i^c)^{-1}$ . Aggregate equilibrium profits in the market are given by

$$\begin{aligned} \Pi^m = & \frac{(P-r)^2}{2} \left[ \frac{1}{c_1 f(\gamma_1^m, \nu_1^m)} + \frac{1}{c_2 f(\gamma_2^m, \nu_2^m)} \right] \\ & - \frac{(P-r)^4}{2} \left[ \frac{a^2}{4} \left( \frac{1}{c_1^2} + \frac{1}{c_2^2} \right) + \frac{(1-a)^2}{4} \left( \frac{1}{c_1^2} + \frac{1}{c_2^2} \right) \right] - F \end{aligned}$$

with  $f(\gamma_i^m, \nu_i^m) = (a\gamma_i^m + (1-a)\nu_i^m)^{-1}$ .

After some algebraic manipulations, we derive<sup>38</sup>

$$\Pi^c > \Pi^m \Leftrightarrow a > a_\pi^m \equiv \frac{1}{1 + \frac{1}{2} \left( \frac{\tau_1' - 6c_1c_2\mu_1\mu_2 + \tau_2'}{\tau_1 + \tau_2} \right)^{1/2}},$$

with  $\tau_i = c_i^2 [\mu_j^3(3\mu_j - 4) + 1] > 0$ , and  $\tau_i' = c_i^2 [3\mu_j^2(5 - 4\mu_j) - 4]$ ,  $i, j \in \{1, 2\}$ ,  $i \neq j$ .

It follows that  $a_\pi^m \in [0, 1]$ . However, it is not guaranteed that  $a_\pi^m \in [0, 1]$  exists because  $\Gamma = \frac{\tau_1' - 6c_1c_2\mu_1\mu_2 + \tau_2'}{\tau_1 + \tau_2}$  can be negative. We derive that  $a_\pi^m$  exists only if (i) members in the cooperative are sufficiently similar in terms of their cost structure, i.e.,  $\frac{c_2}{c_1} < c^m$ , and (ii) the large member does not receive too large a share of the cooperative's profit, i.e.,  $\mu_1 \in (\underline{\mu}_1^m, \bar{\mu}_1^m)$ . For example, if  $c_1 = c_2 = c$ , we obtain

$$\Gamma = \frac{-5 + 24\mu_1\mu_2}{1 + 6\mu_1^2\mu_2^2} > 0 \Leftrightarrow \mu_1 \in (\underline{\mu}_1^m, \bar{\mu}_1^m) = \left( \frac{1}{12} [6 - \sqrt{6}], \frac{1}{12} [6 + \sqrt{6}] \right)$$

That is,  $\mu_1$  has to be in the interval  $(\underline{\mu}_1^m, \bar{\mu}_1^m)$  to guarantee the existence of  $a_\pi^m$ . If  $c_1 \neq c_2$ , it can be shown that an increasing cost heterogeneity  $\frac{c_2}{c_1}$  shrinks the interval  $(\underline{\mu}_1^m, \bar{\mu}_1^m)$ .

That is, for a given  $c_1$  it holds  $\frac{\partial \underline{\mu}_1^m}{\partial c_2} > 0$  and  $\frac{\partial \bar{\mu}_1^m}{\partial c_2} < 0$ . If the cost heterogeneity is sufficiently large with  $\frac{c_2}{c_1} > c^m$ , then no  $\mu_1$  exists such that  $\Gamma > 0$ . In this case,  $\Pi^c < \Pi^m \forall a \in (0, 1)$ .

## A.7 Proof of Lemma 8

With  $f(\gamma^c, \nu_i^c) = (a\gamma^c + (1-a)\nu_i^c)^{-1}$  and  $f(\gamma_i^m, \nu_i^m) = (a\gamma_i^m + (1-a)\nu_i^m)^{-1}$ , we derive the following results.

<sup>38</sup>Formally, the equation  $\Pi^c - \Pi^m = 0$  has two roots  $a_1$  and  $a_2$ . However, we can rule out one root.

(i) Aggregate equilibrium outputs in the cooperative and market are given by

$$Q^c = (P-r) \left[ \frac{\mu_1}{c_1 f(\gamma^c, \nu_1^c)} + \frac{\mu_2}{c_2 f(\gamma^c, \nu_2^c)} \right] \text{ and } Q^m = (P-r) \left[ \frac{1}{c_1 f(\gamma_1^m, \nu_1^m)} + \frac{1}{c_2 f(\gamma_2^m, \nu_2^m)} \right] \quad (19)$$

We compute

$$Q^c > Q^m \Leftrightarrow a > a_q^m(\mu_1, c_1, c_2) \equiv \frac{1}{1 + \frac{\left(\frac{1}{2}[\tau_1 + \tau_2][\tau_1' + 6c_1 c_2 \mu_1 \mu_2 + \tau_2']\right)^{1/2}}{\tau_1 + \tau_2}}$$

with  $\tau_1 = c_1^2(1 - \mu_2^3)$ ,  $\tau_2 = c_2^2(1 - \mu_1^3)$  and  $\tau_1' = c_1^2(3\mu_2^2 - 2)$ ,  $\tau_2' = c_2^2(3\mu_1^2 - 2)$ .

(ii) Aggregate production costs in the cooperative and market are given by

$$C_p^c = C_{p,1}(\hat{q}_1^c, \gamma^c, \nu_1^c) + C_{p,2}(\hat{q}_2^c, \gamma^c, \nu_2^c) = \frac{(P-r)^2}{2} \left( \frac{\mu_1^2}{c_1 f(\gamma^c, \nu_1^c)} + \frac{\mu_2^2}{c_2 f(\gamma^c, \nu_2^c)} \right) \quad (20)$$

$$C_p^m = C_{p,1}(\hat{q}_1^m, \gamma_1^m, \nu_1^m) + C_{p,2}(\hat{q}_2^m, \gamma_2^m, \nu_2^m) = \frac{(P-r)^2}{2} \left( \frac{1}{c_1 f(\gamma_1^m, \nu_1^m)} + \frac{1}{c_2 f(\gamma_2^m, \nu_2^m)} \right)$$

We compute

$$C_p^c > C_p^m \Leftrightarrow a > a_p^m(\mu_1, c_1, c_2) \equiv \frac{1}{1 + \frac{\left(\frac{1}{2}[\tau_1 + \tau_2][\tau_1' + 3c_1 c_2 \mu_1 \mu_2 (\mu_1 + \mu_2) + \tau_2']\right)^{1/2}}{\tau_1 + \tau_2}}$$

with  $\tau_1 = c_1^2(1 - \mu_2^4)$ ,  $\tau_2 = c_2^2(1 - \mu_1^4)$  and  $\tau_1' = c_1^2(3\mu_2^2 - 2)$ ,  $\tau_2' = c_2^2(3\mu_1^2 - 2)$ .

(iii) Aggregate knowledge acquisition costs in the cooperative and market are given by

$$C_k^c = C_\gamma(\gamma^c) + C_\nu(\nu_1^c) + C_\nu(\nu_2^c)$$

$$= \frac{(P-r)^4}{8} \left[ \frac{9a^2}{4} \left( \frac{c_2 \mu_1 + c_1(1 - \mu_1)}{c_1 c_2} \right)^2 + (1-a)^2 \left( \frac{c_2^2 (\mu_1^2)^2 + c_1^2 (\mu_2^2)^2}{c_1^2 c_2^2} \right) \right] \quad (21)$$

$$C_k^m = C_\gamma(\gamma_1^m) + C_\gamma(\gamma_2^m) + C_\nu(\nu_1^m) + C_\nu(\nu_2^m)$$

$$= \frac{(P-r)^4}{8} \left[ a^2 \left( \frac{1}{c_1^2} + \frac{1}{c_2^2} \right) + (1-a)^2 \left( \frac{1}{c_1^2} + \frac{1}{c_2^2} \right) \right]$$

We compute

$$C_k^c > C_k^m \Leftrightarrow a > a_k^m(\mu_1, c_1, c_2) \equiv \frac{1}{1 + \frac{\left(\frac{1}{4}[\tau_1 + \tau_2][\tau_1' + 18c_1 c_2 \mu_1 \mu_2 + \tau_2']\right)^{1/2}}{\tau_1 + \tau_2}}$$

with  $\tau_1 = c_1^2(1 - \mu_2^4)$ ,  $\tau_2 = c_2^2(1 - \mu_1^4)$  and  $\tau_1' = c_1^2(9\mu_2^2 - 4)$ ,  $\tau_2' = c_2^2(9\mu_1^2 - 4)$ .

Recall from Proposition 1 that  $C_\nu^c - C_\nu^m < 0$  and  $|C_\nu^c - C_\nu^m|$  decreases in  $\mu_1$  and  $a$ . Moreover,  $C_\gamma^c - C_\gamma^m > 0 \Leftrightarrow \mu_1 > \mu_1^{**}$ . If  $\mu_1 > \mu_1^{**}$  holds,  $C_\gamma^c - C_\gamma^m$  increases in  $\mu_1$  and  $a$ , while if  $\mu_1 < \mu_1^{**}$ , then  $|C_\gamma^c - C_\gamma^m|$  decreases in  $\mu_1$  and  $a$ .



## A.8 Proof of Proposition 4

Aggregate equilibrium profits in the cooperative are given by (18), while aggregate equilibrium profits in the hierarchy are given by

$$\begin{aligned}\Pi^h = & \frac{(P-r)^2}{2} \left[ \frac{1}{c_1 f(\gamma^h, \nu_1^h)} + \frac{1}{c_2 f(\gamma^h, \nu_2^h)} \right] \\ & - \frac{(P-r)^4}{8} \left[ \frac{a^2}{\lambda_\gamma} \left( \frac{(c_1 + c_2)^2}{c_1^2 c_2^2} \right) + \frac{(1-a)^2}{\lambda_\nu} \left( \frac{1}{c_1^2} + \frac{1}{c_2^2} \right) \right] - F\end{aligned}$$

After some algebraic manipulations, we derive<sup>39</sup>

$$\Pi^c > \Pi^h \Leftrightarrow a < a_\pi^h \equiv \frac{1}{1 - \frac{\Gamma^{1/2}}{2\lambda_\gamma(\tau_1 + \tau_2)}},$$

with  $\Gamma = \lambda_\gamma \lambda_\nu [\tau_1 + \tau_2] [\tau_1' - 2c_1 c_2 (4 + 3\lambda_\gamma \mu_1 \mu_2 (2(\mu_1 + \mu_2) - 5) + \tau_2') + \tau_2']$  and  $\tau_i = c_i^2 + c_i^2 [\lambda_\nu \mu_j^3 (3\mu_j - 4)]$ ,  $\tau_i' = c_i^2 [3\lambda_\gamma \mu_j^2 (5 - 4\mu_j) - 4]$ ,  $i, j \in \{1, 2\}$ ,  $i \neq j$ . However, it is not guaranteed that  $a_\pi^h$  exists because  $\Gamma$  can be negative. We derive that  $\Gamma > 0$  and therefore the existence of  $a_\pi^h \in [0, 1]$  in the case that (i) the monitoring problem in the hierarchy is present, i.e.,  $\lambda_\gamma > 1$  and/or  $\lambda_\nu > 1$  and (ii) the large member in the cooperative receives a sufficiently large share of the cooperative's profit, i.e.,  $\mu_1 > \mu_1^h$ , where,  $\mu_1^h$  is in the interval of feasible  $\mu_1$  if the cost heterogeneity is sufficiently large.

## A.9 Proof of Lemma 9

With  $f(\gamma^c, \nu_i^c) = (a\gamma^c + (1-a)\nu_i^c)^{-1}$  and  $f(\gamma^h, \nu_i^h) = (a\gamma^h + (1-a)\nu_i^h)^{-1}$ , we derive the following results.

(i) Aggregate equilibrium output in the cooperative is given by (19), while aggregate output in hierarchy is given by

$$Q^h = (P-r) \left[ \frac{1}{c_1 f(\gamma^h, \nu_1^h)} + \frac{1}{c_2 f(\gamma^h, \nu_2^h)} \right]$$

We compute

$$Q^c > Q^h \Leftrightarrow a < a_q^h(\mu_1, c_1, c_2) \equiv \frac{1}{1 - \frac{(\lambda_\gamma \lambda_\nu / 2 [\tau_1 + \tau_2] [\tau_1' + 2c_1 c_2 (3\lambda_\gamma \mu_1 \mu_2 - 2) + \tau_2'])^{1/2}}{\lambda_\gamma (\tau_1 + \tau_2)}}$$

with  $\tau_1 = c_1^2 (1 - \lambda_\nu \mu_2^3)$ ,  $\tau_2 = c_2^2 (1 - \lambda_\nu \mu_1^3)$  and  $\tau_1' = c_1^2 (3\lambda_\gamma \mu_2^2 - 2)$ ,  $\tau_2' = c_2^2 (3\lambda_\gamma \mu_1^2 - 2)$ .

(ii) Aggregate production costs in the cooperative are given by (20), while aggregate production costs in the hierarchy are given by

$$\begin{aligned}C_p^h &= C_{p,1}(\hat{q}_1^h, \gamma^h, \nu_1^h) + C_{p,2}(\hat{q}_2^h, \gamma^h, \nu_2^h) \\ &= \frac{(P-r)^2}{2} \left( \frac{1}{c_1 f(\gamma^h, \nu_1^h)} + \frac{1}{c_2 f(\gamma^h, \nu_2^h)} \right)\end{aligned}$$

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<sup>39</sup>Formally, the equation  $\Pi^c - \Pi^h = 0$  has two roots  $a_1$  and  $a_2$ . However, we can rule out one root.

We compute

$$C_p^c > C_p^h \Leftrightarrow a < a_p^h(\mu_1, c_1, c_2) \equiv \frac{1}{1 - \frac{(\lambda_\gamma \lambda_\nu / 2 [\tau_1 + \tau_2] [\tau_1' + c_1 c_2 (3\lambda_\gamma \mu_1 \mu_2 (\mu_1 + \mu_2) - 4) + \tau_2'])^{1/2}}{\lambda_\gamma (\tau_1 + \tau_2)}}$$

with  $\tau_1 = c_1^2(1 - \lambda_\nu \mu_2^4)$ ,  $\tau_2 = c_2^2(1 - \lambda_\nu \mu_1^4)$  and  $\tau_1' = c_1^2(3\lambda_\gamma \mu_2^3 - 2)$ ,  $\tau_2' = c_2^2(3\lambda_\gamma \mu_1^3 - 2)$ .

(iii) Aggregate knowledge acquisition costs in the cooperative are given by (21), while aggregate knowledge acquisition costs in the hierarchy are given by

$$\begin{aligned} C_k^h &= C_\gamma(\gamma^h) + C_\nu(\nu_1^h) + C_\nu(\nu_2^h) \\ &= \frac{(P-r)^4}{8} \left[ \frac{a^2}{\lambda_\gamma} \left( \frac{(c_1 + c_2)^2}{c_1^2 c_2^2} \right) + \frac{(1-a)^2}{\lambda_\nu} \left( \frac{1}{c_1^2} + \frac{1}{c_2^2} \right) \right] \end{aligned}$$

We compute

$$C_k^c > C_k^h \Leftrightarrow a > a_k^h(\mu_1, c_1, c_2) \equiv \frac{1}{1 + \frac{(\lambda_\gamma^2 \lambda_\nu^2 / 2 [\tau_1 + \tau_2] [\tau_1' + \tau_2'] [\tau_1'' + \tau_2''])^{1/2}}{\lambda_\gamma^2 (\tau_1 + \tau_2)}}$$

with  $\tau_1 = c_1^2(1 - \lambda_\nu^2 \mu_2^4)$ ,  $\tau_2 = c_2^2(1 - \lambda_\nu^2 \mu_1^4)$  and  $\tau_1' = c_1(3\lambda_\gamma \mu_2 - 2)$ ,  $\tau_2' = c_2(3\lambda_\gamma \mu_1 - 2)$  and  $\tau_1'' = c_1(3\lambda_\gamma \mu_2 + 2)$ ,  $\tau_2'' = c_2(3\lambda_\gamma \mu_1 + 2)$

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