The Knowledge Economics of Cooperatives

Helmut M. Dietl, Martin Grossmann, Markus Lang*
University of Zurich

Abstract

This paper compares markets, cooperatives and hierarchies in terms of organizational efficiency. In particular, we analyze the knowledge economics of these three alternative forms of organization. We show that the three alternatives differ with respect to the acquisition of general versus idiosyncratic knowledge and with respect to their effectiveness to solve hold up problems. Markets are a marvel with respect to the aggregation and communication of idiosyncratic knowledge, but cause hold up problems when actors have to make specific investments. Cooperatives and hierarchies, on the other hand, solve hold up problems and effectively economize on the acquisition and use of general knowledge. Moreover, we show that cooperatives dominate markets (hierarchies) in terms of efficiency if the acquisition of general (idiosyncratic) knowledge is important for value creation.

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*Corresponding author: Markus Lang. All authors from University of Zurich, Institute for Strategy and Business Economics, Plattenstrasse 14, 8032 Zurich, Switzerland. Phone +41 (0)44 634 53 11, Fax +41 (0)44 634 53 29, E-mails: helmut.dietl@isu.uzh.ch, martin.grossmann@isu.uzh.ch markus.lang@isu.uzh.ch

1 Introduction

Today, many industries are dominated by firms which are organized as business corporations. Owners of these corporations are investors. However, there are other organizational forms such as cooperatives. Cooperatives are typically owned by consumers, workers or producers. The voting power varies among the different organizational forms. In a cooperative, each member has a per capita voting power, whereas in a business corporation the capital investments are decisive. But which organizational form is preferable in a specific industry? Apparently, the economic environment has a large impact on the efficiency of an organizational form. Williamson (1979) and Klein et al. (1978) discuss the structure of ownership in relation to specific investments.

In this paper, we combine two topics which are often discussed separately in the literature: A cooperative as an organizational form and the transfer of knowledge. We develop a model in order to compare cooperatives with other organizational forms and simultaneously incorporate elements of idiosyncratic and general knowledge.

The particularity of the model is that agents have two random cost components. First, agents' costs are affected by a *common* component which influences all agents in an identical manner. This common component could be interpreted as a typical cost element in a specific industrial sector. Second, the agents' costs are affected by an *individual* component. This reflects the fact that every agent is exposed to individual circumstances in a given industrial sector. Nevertheless, the agents have the possibility to invest specifically in order to gather information about the two components and subsequently alter the costs' effect. Hence, these investments reflect the incorporation of knowledge into the model as discussed above. We postulate that it is the combination of the organizational form and knowledge which induces a cooperative organization to be more efficient in some specific economic environments.

There exists a broad literature both on the theory of cooperatives and knowledge. Bonus (1986) combines both topics. He describes two forces which are critical in cooperatives: On the one hand, there must be benefits of collective organization. Bonus denominates these benefits as *centripetal forces* in a cooperative. For instance, members of a specific cooperative do not purchase products on their own. Instead, they jointly buy these products by their purchasing cooperative.

On the other hand, there are benefits of independent operations leading to *centrifugal forces* in a cooperative. Bonus points out that economies of scale and some degree of monopoly power are often accompanying the formation of cooperatives. But these motives are not the critical sources from his point of view. He concludes that the availability of local information as well as a 'cooperative spirit' are the driving forces in order to form cooperatives. Bonus emphasizes that trust is a productive resource in a cooperative. All members know that they own the cooperative and that they depend on each other. We resume the importance of local information and knowledge in a cooperative in the next section.

Other authors have discussed the particularity of cooperatives, e.g. Enke (1945), Phillips (1953) and Hansmann (1988). Hansmann (1988) compares conventional investor-owned firms with cooperatives. He concludes that market contracts are costly in case of asymmetric information or market power. Then, a union of firms might reduce costs. He points out two cost components: Market contracting and ownership costs. In case of a consumer cooperative such as a cooperative book store on a campus, for instance, the market power may be a reason to form a cooperative according to Hansmann. A cooperative is adequate since economies of scales can be exploited. Ownership costs are low since students have more or less long run incentives to buy books in this store and students are easily unionized because interests may be homogeneous. Hansmann also analyzes the farm supply cooperatives in the U.S. and gets similar results as in the cooperative book store example. Contrary to Bonus (1986), he points out that market power constitutes an important stimulation to form cooperatives in the farm supply business.

Porter and Scully (1987) empirically test whether plants in cooperatives are more efficient than noncooperative firms in the U.S. fluid-milk processing market. Their results indicate that self-governed plants are significantly more efficient than cooperatives. According to their empirical tests, a cooperative firm could increase output by 32.4 percent if it were reorganized as a self-governed firm without using supplemental inputs.

We have already mentioned that *general* and *idiosyncratic* knowledge about firms' environment might influence the efficiency of a specific organizational form. Idiosyncratic knowledge reflects the knowledge about specific circumstances in an individual firm. This knowledge is highly depending on individual experience and therefore cannot be communicated easily. For instance, consider a farmer managing his crops and cattle. It is nearly impossible to specify adequate behaviour accounting for every possible contingency. However, an experienced farmer will know how to behave in different circumstances based on his experience.

Another example has been given by Polanyi (1998) who describes the process of learning to ride a bicycle. Even if Lance Armstrong explained riding with physical terminology to a layman, the latter would fall from the bicycle. Both examples emphasize the importance of experience regarding idiosyncratic knowledge. Hayek (1945) postulates that it seems to be reasonable that people working in a specific firm should get the decision rights because they best know the local conditions. He points out, however, that general knowledge often can be communicated between firms costlessly. A further paper about specific and general knowledge has been written by Jensen and Meckling (1995). They analyze how transfer costs of knowledge influence the decentralization of decision rights.

This paper has the following structure: Section two presents the main assumptions and timing of the model. In section three, we solve the model in three different market environments. First, we assume that firms do not cooperate, and a central company acts self-governed as a buyer of the firms' products. We will denote this case as the 'market solution' because all agents interact autonomously in markets. Second, we examine a market situation in which all firms are part of a cooperative. This will be called the 'cooperative solution'. Third, we consider a vertically integrated environment in which the central company owns all firms. By reason of the dominant position of the central company we will call this case as the 'hierarchical solution'. In section five, we present two applications of the model and sum up the main results.

2 Model Setup

We consider a large number of identical and (expected) profit maximizing firms, indexed $i \in \{1, .., n\}$ with $n > 1$, that have the opportunity to produce two different intermediate products S and V, using two linear production functions. The first product S is produced by the linear technology $f(s_i) = s_i$ with a convex cost function $c_s(s_i) = \frac{1}{2}s_i^2$.[1] The output $f(s_i)$ can be sold to a profit maximizing monopolist at a price p_s chosen by this monopolist. The monopolist transforms the intermediate product into a final good. We assume that the monopolist neither incurs costs through this transformation nor has an outside option. Finally, the monopolist resells the final good at an exogenous world market price $p_w > 0$.[2]

As mentioned, firm $i \in \{1, .., n\}$ also has the possibility to produce a second intermediate product V which can be sold at an outside market at a normalized price $p_v = 1$. The technology for the second product is similar to the technology of the first product. Thus, the production function of the second product is given

[1] Note that there is a second cost component which will be introduced below.

[2] Thus, the monopolist acts as a price taker with respect to the world market, but simultaneously, the monopolist sets a price p_s in the "inside" market as a price setter.

by $g(v_i) = v_i$ and cost function $c_v(v_i) = \frac{1}{2}\gamma v_i^2$. The parameter $\gamma > 1$ reflects the degree of specificity of investments into the second product. A high γ implies that marginal costs of producing the second product relatively to the first product are high.

A firm will sell the product V on the outside market if it is not satisfied with the monopolist's price p_s for the first intermediate product S. This will be the case if the proposed price p_s by the monopolist is too low such that the firm would realize higher profits on the outside market compared to a trade with the monopolist on the inside market. Therefore, the second product can be interpreted as an investment into an outside option. We assume that a firm chooses to interact with the monopolist if the firm is indifferent between the monopolist's offer and the outside option.

Moreover, we assume that a firm can either sell the first intermediate product S or the second intermediate product V but not both intermediate products together. One intermediate product loses all of its value depending on the firm's decision on which market it wants to be active. Nevertheless, the firm is facing the two costs functions $c_s(s_i) = \frac{1}{2}s_i^2$ and $c_v(v_i) = \frac{1}{2}\gamma v_i^2$ independent of the decision which intermediate product will be sold in the end. Therefore, $c_s(s_i)$ and $c_v(v_i)$ represent sunk costs.

Why should a firm invest into its outside option if one product loses all of its value? Consider the following example: The higher a firms' value of its outside option is, the more a firm exerts pressure on the monopolist to increase the price p_s so that the firm favours the monopolist's offer. For instance, in the European football leagues, 14 clubs have allied in order to increase their negotiating power against the national and international associations (e.g. UEFA). The so-called G-14 clubs threaten to establish a new league. This foundation can be interpreted as an outside option for the G-14. If clubs decide to play anyway in the up to now existing national and international leagues, the value of this outside option is zero ex post. However, ex ante it increases the G-14's bargaining power. Note that the threat implies costs for the G-14 and these costs represent sunk costs.

So far, we have delineated the production side and one part of the costs. Next, we reconsider the cost functions of the model. We assume that the costs consist of *two components*. Firms generate the first cost component $c_s(s_i)$ and $c_v(v_i)$ by producing the two products as described above. Now, we introduce a second cost component, denoted by c_i, which is composed itself out of *two elements*: The first element represents costs which influence all firms in an identical manner illustrating a common cost factor denoted $\widetilde{\theta}$. The second element characterizes a firm specific idiosyncratic cost denoted $\widetilde{\varepsilon}_i$. We assume that $\widetilde{\theta}$ and $\widetilde{\varepsilon}_i$ are independent, continuously distributed random variables with a first moment equal to zero and a finite second moment $\sigma_\theta^2 > 0$ and $\sigma_{\varepsilon_i}^2 = \sigma_\varepsilon^2 > 0 \; \forall i \in \{1, .., n\}$.[3]

Moreover, firms are able to acquire knowledge about the realization of the random variables $\widetilde{\theta}$ and/or $\widetilde{\varepsilon}_i$ by investing an exogenous amount $k_\theta > 0$ and/or $k_\varepsilon > 0$.[4] The realizations of the random variables are denoted θ and ε_i, respectively.

We formalize the second cost component c_i by the following expression:

$$c_i = (\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2.$$

The variable $x_i \geq 0$ indicates a choice variable for firm i in order to react optimally contingent on the information about the realization of the random variables $\widetilde{\theta}$ and $\widetilde{\varepsilon}_i$. Note that firm i has an incentive to acquire knowledge about the realization of $\widetilde{\theta}$ and $\widetilde{\varepsilon}_i$ if the learning costs are lower than the expected costs without learning.[5]

To illustrate the second cost component c_i, consider the example of a farmer (representing a firm) working on his farmland. The harvest is influenced both by the climate (common cost element) which affects all farmers in an identical manner, and by the quality of the soil (idiosyncratic cost element) which is different between the farmlands. Now, a farmer has the opportunity to invest into a technology to detect the characteristics of his farmland and/or he could buy some information about weather forecast or the climate at a research institute such that he could optimally (re-)act to the characteristics of his farmland and/or to weather changes.

In the next lemma, we derive conditions under which a firm has an incentive to invest k_θ and/or k_ε in order to acquire knowledge about θ and/or ε_i:

Lemma 1
(i) If $k_\theta \leq \sigma_\theta^2$ and $k_\varepsilon \leq \sigma_\varepsilon^2$ then firm i will invest k_θ and k_ε to detect θ and ε_i.
(ii) If $k_\theta \leq \sigma_\theta^2$ and $k_\varepsilon > \sigma_\varepsilon^2$ then firm i will invest k_θ but not k_ε to detect θ.
(iii) If $k_\theta > \sigma_\theta^2$ and $k_\varepsilon \leq \sigma_\varepsilon^2$ then firm i will invest k_ε but not k_θ to detect ε_i.
(iv) If $k_\theta > \sigma_\theta^2$ and $k_\varepsilon > \sigma_\varepsilon^2$ then firm i will neither invest k_θ nor k_ε.

Proof. Straightforward. ■

The lemma shows that if learning costs are sufficiently low, i.e. $k_\theta \leq \sigma_\theta^2$ and $k_\varepsilon \leq \sigma_\varepsilon^2$, firm i will invest k_θ and k_ε in order to acquire general and idiosyncratic

[3]Since the random variable $\widetilde{\theta}$ reflects the common effect on all firms it has no firm specific subscript i, whereas $\widetilde{\varepsilon}_i$ is a firm specific random variable with subscript i.

[4]Note that we do not explicitely model the process how a firm acquires knowledge. See e.g. Ba et al. (2001) who analyze the optimal investment in knowledge within a firm using a Groves-Clarke-type double auction. For more about auctions, see e.g. Engelbrecht-Wiggans and Weber (1979), Engelbrecht-Wiggans (1980), Engelbrecht-Wiggans (1987), Hausch (1986) and Rothkopf and Harstad (1994).

[5]See Lemma 1 below.

knowledge to detect the realization of $\widetilde{\theta}$ and $\widetilde{\varepsilon}_i$. In this case, expected costs $E[c_i] = E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]$ are minimized by setting $x_i^* = \theta + \varepsilon_i$ and are given by $E[c_i \mid \theta, \varepsilon_i \text{ known}] = k_\theta + k_\varepsilon$ (case (i)). If, however, only the learning costs k_θ to acquire general knowledge θ are sufficiently low but not the learning costs k_ε to acquire idiosyncratic knowledge ε_i, i.e. $k_\theta \leq \sigma_\theta^2$ and $k_\varepsilon > \sigma_\varepsilon^2$, then firm i will only invest k_θ but not k_ε. In this case, expected costs are minimized by setting $x_i^* = \theta$ and are given by $E[c_i \mid \text{only } \theta \text{ known}] = k_\theta + \sigma_\varepsilon^2$ (case (ii)). In case (iii), expected costs are derived as $E[c_i \mid \text{only } \varepsilon_i \text{ known}] = k_\varepsilon + \sigma_\theta^2$ by setting $x_i^* = \varepsilon_i$. In case (iv), expected costs are derived as $E[c_i \mid \theta, \varepsilon_i \text{ unknown}] = \sigma_\theta^2 + \sigma_\varepsilon^2$ by setting $x_i^* = 0$.

3 Equilibrium Analysis

We consider the optimal behavior of the firms and the monopolist in three different forms of organization. In the first scenario, all firms act autonomously. They do not cooperate, and the market is vertically separated. The monopolist also acts self-governed. Second, we examine the optimal behavior in a cooperative. There, we assume that the firms together "own" the monopolist and share the monopolist's profit which has to be nonnegative. Third, we analyze a vertically integrated market. In this scenario, a firm acts as a monopolist's employee. This structure implies that the monopolist owns all downstream firms. It is important to note that we just focus on the producer side in this model. We abstract from consumer surplus. Thus, in this paper efficiency refers to the aggregate profits of firms.

3.1 Market Form of Organization

In this section, we consider a market form of organization in which each firm $i \in \{1, .., n\}$ maximizes its profit individually. The monopolist also acts autonomously. We model a four-period setup where the timing is as follows: In period 1, nature determines θ and ε_i unobserved by all firms. In period 2, firm i decides whether to invest k_θ and/or k_ε to discover the values θ and/or ε_i after having observed the exogenous variables $(p_w, p_v, k_\theta, k_\varepsilon, \sigma_\theta^2, \sigma_\varepsilon^2)$. Moreover, firm i chooses both s_i and v_i. In period 3, the monopolist sets a price p_s after having observed the chosen values s_i and v_i of firm i and the exogenous variables $(p_w, p_v, k_\theta, k_\varepsilon, \sigma_\theta^2, \sigma_\varepsilon^2)$. In period 4, firm i decides whether to sell the product to the monopolist or to realize its outside option at price p_v. Finally, the payoffs are realized.

We solve this model by applying backward induction: In the last period, firm i

sells the intermediate product S to the monopolist at price p_s if and only if expected profits are at least as high as expected profits generated in the outside option.[6] The monopolist anticipates this reaction in period 3 and also bears in mind that its own outside option is zero. Thus, the monopolist offers a price p_s (if $p_s \leqslant p_w$) such that firm i is just indifferent between its outside option and selling product S to the monopolist. As a consequence, the monopolist maximizes the sum of revenues $p_w s_i$ minus costs $p_s s_i$ over all firms $i \in \{1, ..., n\}$ with respect to p_s under the restriction that all firms prefer this offer to the outside option. In period 3, the monopolist thus solves the following maximization problem:

$$\max_{p_s} \left(\sum_{i=1}^{n} (p_w s_i - p_s s_i) \right)$$

$$\text{s.t. } p_s s_i - \underbrace{\left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2} s_i^2 \right)}_{\text{first cost component}} - \underbrace{E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]}_{\text{second cost component}} \geq p_v \cdot v_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2} s_i^2 \right) \tag{1}$$

$$- E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]$$

The monopolist chooses the minimum price p_s such that every firm is just indifferent between this offer and its outside option. We derive the solution to problem (1) in the next lemma:

Lemma 2
In period 3, the monopolist sets the price for the intermediate product S as follows:

$$p_s^*(s_i, v_i) = \begin{cases} \frac{v_i}{s_i} & \text{if } p_w \geqslant p_s^* = \frac{v_i}{s_i} \\ 0 & \text{if } p_w < p_s^* = \frac{v_i}{s_i} \end{cases} \tag{2}$$

Proof. See Appendix. ■

The optimal choice of p_s^* is $\frac{v_i}{s_i}$ if the monopolist's profit is nonnegative. Otherwise the monopolist sets $p_s^* = 0$. In case of nonnegative profits, the monopolist offers a higher price $p_s^* = \frac{v_i}{s_i}$ if firms invest relatively more in the outside option. Intuitively, a higher value of the firms' outside option forces the monopolist to offer a higher equilibrium price for the intermediate product S.

In period 2, firm $i \in \{1, .., n\}$ chooses s_i and v_i, anticipating the monopolist's price setting behavior according to (2). We have to differentiate two cases in order to derive the firms' optimal behavior. In case (i), the monopolists sets $p_s^*(s_i, v_i) = \frac{v_i}{s_i}$ and in case (ii) the monopolist sets $p_s^*(s_i, v_i) = 0$ in period 3.

[6] Note that in period 4, firm i's costs represent sunk costs because s_i and v_i were chosen already in period 2.

Case (i): Monopolist sets $p_s^* = \frac{v_i}{s_i}$ in period 3. In this case, firm $i \in \{1, .., n\}$ maximizes its expected profits under the constraint that the monopolist realizes nonnegative profits (otherwise the monopolist would set $p_s^* = 0$). Thus, firm i solves the following maximization problem:

$$\max_{s_i, v_i} \left(p_s^* s_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2} s_i^2 \right) - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] \right) \quad \text{s.t.} \quad p_w s_i - p_s^* s_i \geq 0 \tag{3}$$

The first term in the maximization problem (3) represents firm i's revenue. The second term characterizes the costs of producing s_i and v_i (first cost component). Finally, the third term indicates the expected costs from the idiosyncratic and common cost element (second cost component).

The solution to the maximization problem (3) is derived in the following lemma:

Lemma 3
If the monopolist sets $p_s^* = \frac{v_i}{s_i}$ in period 3, firm i will choose $(s_i^*, v_i^*) = \left(\frac{p_w}{1+\gamma p_w^2}, \frac{p_w^2}{1+\gamma p_w^2} \right)$ in period 2. The price for product S is then given by $p_s^* = p_w$ such that firm i's (expected) profit is given by

$$E[\widehat{\pi}_i^m] = \frac{1}{2} \frac{p_w^2}{1+\gamma p_w^2} - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] = \begin{cases} \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - \sigma_\theta^2 - \sigma_\varepsilon^2 & \textit{if } k_\theta > \sigma_\theta^2 \textit{ and } k_\varepsilon > \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - k_\theta - k_\varepsilon & \textit{if } k_\theta \leqslant \sigma_\theta^2 \textit{ and } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - \sigma_\theta^2 - k_\varepsilon & \textit{if } k_\theta > \sigma_\theta^2 \textit{ and } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - k_\theta - \sigma_\varepsilon^2 & \textit{if } k_\theta \leqslant \sigma_\theta^2 \textit{ and } k_\varepsilon > \sigma_\varepsilon^2 \end{cases}$$

Proof. See Appendix. ■

The decision of firm i to invest in idiosyncratic and/or general knowledge depends on the learning costs $(k_\theta, k_\varepsilon)$ as well as the variances $(\sigma_\theta^2, \sigma_\varepsilon^2)$ of the idiosyncratic and common cost element (see Lemma 1).

Case (ii): Monopolist sets $p_s^* = 0$ in period 3. In this case, firm i will only invest in its outside option in period 2, i.e. it sets $s_i^* = 0$ since it anticipates the price setting behavior of the monopolist in period 3. Thus, firm i solves the following maximization problem:

$$\max_{v_i} \left(v_i - \frac{1}{2}\gamma v_i^2 - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] \right) \tag{4}$$

The solution to the maximization problem (4) is derived in the following lemma:

Lemma 4
If the monopolist sets $p_s^* = 0$ in period 3, firm i will only invest in its outside

option in period 2 *by choosing* $(s_i^*, v_i^*) = \left(0, \frac{1}{\gamma}\right)$ *such that firm i's (expected) profit is given by*

$$E[\pi_i^m] = \frac{1}{2}\frac{1}{\gamma} - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] = \begin{cases} \frac{1}{2}\frac{1}{\gamma} - \sigma_\theta^2 - \sigma_\varepsilon^2 & \textit{if } k_\theta > \sigma_\theta^2 \textit{ and } k_\varepsilon > \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{1}{\gamma} - k_\theta - k_\varepsilon & \textit{if } k_\theta \leqslant \sigma_\theta^2 \textit{ and } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{1}{\gamma} - \sigma_\theta^2 - k_\varepsilon & \textit{if } k_\theta > \sigma_\theta^2 \textit{ and } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{1}{\gamma} - k_\theta - \sigma_\varepsilon^2 & \textit{if } k_\theta \leqslant \sigma_\theta^2 \textit{ and } k_\varepsilon > \sigma_\varepsilon^2 \end{cases}$$

Proof. Straightforward. ■

The decision of firm i whether to acquire idiosyncratic and/or general knowledge is similar to Lemma 3.

By comparing (expected) profits from Lemmas 3 and 4, we derive the following proposition:

Proposition 1
In period 2, firm i will only invest in its outside option and thus no trade with the monopolist takes place.

Proof. See Appendix. ■

The proposition shows that the trade between the firms and the monopolist fails completely in a market scenario since firm i's (expected) profit from a trade with the monopolist is lower than the (expected) profit from investing into the outside option only. This replicates the well-known hold-up problem. The firms anticipate the monopolist's pressure after having specifically invested. As a consequence, no firm will invest in the intermediate product S. The intuition behind this result is as follows: Firm i's revenue is independent of the choice s_i because the monopolist sets a price such that the firm is indifferent between selling its product to the monopolist and realizing its outside option. However, firm i's costs are increasing in s_i. Therefore, it is optimal for firm i not to invest in the intermediate product S, i.e. it is optimal to choose $s_i^* = 0$.

3.2 Cooperative Form of Organization

In this section, we consider an organization form in which all firms align with each other in a cooperative, i.e. the firms together "own" the monopolist and share the monopolist's profit. It is obvious that in this case, firms have no incentive to invest in their outside option, i.e. firm i will set $v_i^* = 0$.

Furthermore, we assume that the cost k_θ of acquiring knowledge about the common cost element $\widetilde{\theta}$ has to be paid only once by the cooperative since the realized θ can be communicated to all firms without any additional costs.[7] The learning costs are then shared equally by the n firms, i.e. each firm has to pay $\frac{1}{n}k_\theta$. We assume, however, that this is not possible concerning the idiosyncratic cost element $\widetilde{\varepsilon}_i$. Similar to the market scenario, each firm $i \in \{1, .., n\}$ has to invest k_ε in order to acquire knowledge about the realization of $\widetilde{\varepsilon}_i$.

In a cooperative, it is not evident how the price p_s is determined. A committee would have to set this price. However, we do not explicitly consider the price-setting mechanism. Instead, we assume that p_s is chosen as high as possible so that firms get the highest profits but under the condition that the cooperative itself makes nonnegative profits. The cooperative's profit denoted π^{co} is given by the number of firms n times the revenue per firm minus a possible investment of k_θ for observing θ.

The timing is similar to the market form of organization: In period 1, nature determines θ and ε_i unobserved by all firms. In period 2, firm i (cooperative) decides whether to invest k_ε (k_θ) in order to detect the value ε_i (θ) after having observed the exogenous variables $(p_w, k_\theta, k_\varepsilon, \sigma_\theta^2, \sigma_\varepsilon^2)$. Moreover, firm i chooses s_i. In period 3, the cooperative sets a price p_s after having observed s_i and the exogenous variables $(p_w, k_\theta, k_\varepsilon, \sigma_\theta^2, \sigma_\varepsilon^2)$. Finally, the payoffs are realized.

In order to compare the market and the cooperative form of organization, we have to distinguish three cases depending on whether it is profitable to invest k_θ in order to acquire knowledge about the realization of $\widetilde{\theta}$:

In case (i), we assume that it is profitable to invest k_θ in both the market scenario and the cooperative scenario, i.e. $\frac{1}{n}k_\theta < k_\theta \leq \sigma_\theta^2$. Recall that according to Lemma 1, firms invest k_θ in the market form of organization if $k_\theta \leq \sigma_\theta^2$. In the cooperative scenario, the equivalent condition is given by $\frac{1}{n}k_\theta \leq \sigma_\theta^2$ since the cooperative shares the investment costs k_θ equally among the n firms. In case (ii), we assume that it is profitable to invest k_θ only in the cooperative scenario but not in the market scenario, i.e. $\frac{1}{n}k_\theta \leq \sigma_\theta^2 < k_\theta$. In case (iii), we assume that is is not profitable to invest k_θ neither in the cooperative scenario nor in the market scenario, i.e. $\sigma_\theta^2 < \frac{1}{n}k_\theta < k_\theta$.

Case (i): $\frac{1}{n}k_\theta < k_\theta \leq \sigma_\theta^2$ and case (ii): $\frac{1}{n}k_\theta \leq \sigma_\theta^2 < k_\theta$.[8] In both cases, the cooperative will invest k_θ to acquire knowledge about the common cost element $\widetilde{\theta}$. In period 3, we assume that the cooperative sets the price p_s^* for the intermediate

[7] Note that this assumption is in line with Bonus' argumentation in the introduction. The common cost element $\widetilde{\theta}$ represents a factor for the centripetal forces in a cooperative.

[8] Note that cases (i) and (ii) can be considered together since the analysis in the cooperative scenario is the same.

product S such that the cooperative's profit π^{co} is zero:

$$\pi^{co} = n \cdot (p_w s_i - p_s s_i) - k_\theta = 0 \Leftrightarrow p_s^* = p_w - \frac{k_\theta}{n \cdot s_i}$$

We derive that a higher exogenous world market price p_w, a larger number of firms n or a higher s_i imply a higher price p_s^* for the intermediate product S.[9] Whereas the price p_s^* decreases if investment costs k_θ for detecting the value θ increase.

In period 2, firm i chooses s_i in order to maximize it's expected profit $E[\pi_i^c]$, anticipating the monopolist's price setting behavior in period 3. Thus, firm i solves the following maximization problem:

$$\max_{s_i} E[\pi_i^c] = \left(p_s^* s_i - \frac{1}{2} s_i^2 - E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2] \right) \tag{5}$$

The solution to the maximization problem (5) is derived in the following lemma:

Lemma 5
Suppose $\frac{1}{n} k_\theta \leq \sigma_\theta^2$. *In period 2, firm i will choose* $(s_i^*, v_i^*) = (p_w, 0)$. *The price for product S is then given by* $p_s^* = p_w - \frac{k_\theta}{n \cdot p_w}$ *such that firm i's expected profit is*

$$E[\pi_i^c] = \frac{1}{2} p_w^2 - \frac{1}{n} k_\theta - E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2] = \begin{cases} \frac{1}{2} p_w^2 - \frac{1}{n} k_\theta - \sigma_\varepsilon^2 & \textit{if } k_\varepsilon > \sigma_\varepsilon^2 \\ \frac{1}{2} p_w^2 - \frac{1}{n} k_\theta - k_\varepsilon & \textit{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \end{cases}$$

Proof. See Appendix. ■

Note that the common cost element $\widetilde{\theta}$ does not appear in the term $E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2$ characterizing expected costs for the second cost component. The realization of $\widetilde{\theta}$ is already incorporated in the optimal choice of the variable $x_i \equiv \widehat{x}_i + \theta$ because the cooperative has invested k_θ and has distributed the information about the common cost element $\widetilde{\theta}$ to all firms. The decision of firm i to invest in idiosyncratic knowledge depends on the learning cost k_ε relative to the variance σ_ε^2 of the idiosyncratic cost element. If $k_\varepsilon > \sigma_\varepsilon^2$ then firm i refrains from investing k_ε to learn about $\widetilde{\varepsilon}_i$ such that $E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2] = \sigma_\varepsilon^2$ whereas if $k_\varepsilon \leqslant \sigma_\varepsilon^2$ then firm i will invest k_ε such that $E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2] = 0$.

Case (iii): $\sigma_\theta^2 < \frac{1}{n} k_\theta < k_\theta$**.** In this case, it is not profitible for the cooperative to invest k_θ in order to acquire knowledge about the common cost element $\widetilde{\theta}$. In period 3, the cooperative again sets the price p_s^* such that the cooperative's profit

[9] We assume that the world market price p_w is sufficiently high in order to guarantee a positive price p_s^*.

π^{co} is zero:

$$\pi^{co} = n \cdot (p_w s_i - p_s s_i) = 0 \Leftrightarrow p_s^* = p_w$$

Thus, the cooperative sets the price p_s^* for the intermediate product S equal to the world market price p_w.

In period 2, firm i then chooses s_i in order to maximize it's expected profit $E[\widehat{\pi}_i^c]$, anticipating the monopolist's price setting behavior. Thus, firm i solves the following maximization problem:

$$\max_{s_i} E[\widehat{\pi}_i^c] = \left(p_s^* s_i - \frac{1}{2} s_i^2 - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] \right) \tag{6}$$

The solution to the maximization problem (6) is derived in the following lemma:

Lemma 6
Suppose $\sigma_\theta^2 < \frac{1}{n} k_\theta$. In period 2, firm i will choose $(s_i^*, v_i^*) = (p_w, 0)$. The price for product S is then given by $p_s^* = p_w$ such that firm i's expected profit is

$$E[\widehat{\pi}_i^c] = \frac{1}{2} p_w^2 - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] = \begin{cases} \frac{1}{2} p_w^2 - \sigma_\theta^2 - \sigma_\varepsilon^2 & \text{if } k_\varepsilon > \sigma_\varepsilon^2 \\ \frac{1}{2} p_w^2 - \sigma_\theta^2 - k_\varepsilon & \text{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \end{cases}$$

Proof. Straightforward. ■

In order to derive which form of organization is more efficient in terms of expected profits, we compare expected profits in the cooperative scenario $E[\pi_i^c]$ and $E[\widehat{\pi}_i^c]$, respectively, with expected profits in the market scenario $E[\pi_i^m]$. The results are stated in the following proposition:

Proposition 2
A cooperative organization is more efficient than a market organization if and only if the following inequalities hold:

$$\text{Case (i):} \quad k_\theta \frac{2(n-1)}{n} > \frac{1}{\gamma} - p_w^2 \tag{7}$$

$$\text{Case (ii):} \quad 2\left(\sigma_\theta^2 - \frac{1}{n} k_\theta\right) > \frac{1}{\gamma} - p_w^2 \tag{8}$$

$$\text{Case (iii):} \quad p_w^2 > \frac{1}{\gamma} \tag{9}$$

Proof. See Appendix. ■

The proposition shows that in the different cases, the cooperative organization is more efficient in terms of profits than the market organization if (7), (8) and (9) holds, respectively.

ad (i): First of all, if the learning costs k_θ to acquire knowledge about common environmental factors θ are relatively high, then a cooperative organization is more efficient than a market organization. The rational for this result lies in the fact that the costs k_θ for detecting the environmental characteristics are shared among all n firms in a cooperative whereas in a market solution firms do not cooperate with each other such that every firm has to bear its own the learning costs k_θ. Formally, an increase in k_θ by one unit decreases firm i's profit by one unit in the market solution whereas the firm i's profit just decreases by $\frac{1}{n}$ in a cooperative solution.

Moreover, a relatively high number n of firms also renders a cooperative organization more efficient than a market organization. The intuition behind this result is similar to the former discussion about investments k_θ in general knowledge. The cost per firm decreases in the number of firms in the cooperative scenario but remains constant in the market scenario.

Another interesting parameter is the coefficient γ which characterizes the specificity of investments into the second product V. A relative high γ implies that the cooperative organization is more efficient than the market organization. Recall that the parameter γ also determines the difference of the marginal costs between the two products S and V. An increasing γ implies that the marginal costs producing the second product V increase. Thus, ceteris paribus a higher γ reduces the revenue in a market solution because a firm's incentive to invest in product V decreases in γ, whereas a higher γ does not influence the profit in a cooperative organization.

Finally, a relatively high exogenous world market price p_w for the first product S leads to a situation where the cooperative scenario is more efficient. In a cooperative, a high world market price p_w is carried forward to the firms by increasing the price p_s, whereas in the market solution the world market price does not influence firms' profit. A marginal increase in p_w increases firm i's revenue in a cooperative but does not alter firm i's revenue in a market solution.

ad (ii): Recall that in this case only the cooperative invests in general knowledge but no firm in the market scenario does so since $\frac{1}{n}k_\theta \leq \sigma_\theta^2 < k_\theta$. The term $\left(\sigma_\theta^2 - \frac{1}{n}k_\theta\right)$ on the left hand side of inequality (8) reflects the difference of firm i's (expected) costs by not learning about the common cost element $\widetilde{\theta}$ and learning about it.[10] If the difference in (expected) costs between a situation where a firm knows about general environmental characteristics (cooperative scenario) and a situation where a firm has no knowledge about these characteristics (market scenario) is relatively high then a cooperative form is more efficient than a market

[10] Note that firm i's expected costs are given by σ_θ^2 if firm i does not invest in general knowledge, otherwise costs are given by $\frac{1}{n}k_\theta$.

organization.

The other parameters γ and p_w on the right hand side of inequality (8) have similar effects than in Part (i) of this proposition. The same holds true for Part (iii) of this proposition.

3.3 Hierarchical Form of Organization

In this section, we suppose that there is a central company which owns all firms. Hence, we analyze a vertically integrated market form of organization. Firms become the central company's subsidiaries and do not have any outside option since they are property of the central company. In this setting, the central company is able to dictate each subsidiary's output given by s_i^*. In return, the central company pays a fixed wage w if subsidiary i produces the demanded amount s_i^*.[11] We assume that the central company receives the subsidiary's whole profit including its costs except a possible investment of k_ε.[12]

Moreover, the central company has to decide whether to invest k_θ in order to acquire knowledge about the common cost element $\widetilde{\theta}$. Similar to the cooperative scenario, in case of learning, the central company is able to communicate θ to all subsidiaries without additional costs and the learning costs will then be shared equally among the n subsidiaries. The central company therefore has an incentive to acquire general knowledge if $\frac{1}{n}k_\theta \leq \sigma_\theta^2$.

A subsidiary, however, will never invest k_ε in order to acquire knowledge about the realization of the idiosyncratic cost component $\widetilde{\varepsilon}_i$. The reason is that a subsidiary i receives w if it produces the demanded amount s_i^* independent of the subsidiary's profit. As a consequence, there is no incentive for the subsidiary to acquire idiosyncratic knowledge since an investment of k_ε would only lower w.

The timing as follows: In period 1, nature determines θ and ε_i unobserved by all firms. In period 2, the central company decides whether to invest k_θ in order to detect the value θ after having observed the exogenous variables $(p_w, k_\theta, k_\varepsilon, \sigma_\theta^2, \sigma_\varepsilon^2)$. Moreover, the central company dictates subsidiary i to produce s_i^* and pays w to each subsidiary.

The central company maximizes its expected profit denoted $E[\pi_i^{cc}]$ and solves

[11] We simplify the problem here by neglecting the possibility of optimal contracting in hidden actions situations. See, for example, Hart and Holmström (1987) for a broad discussion on this topic.

[12] We justify this assumption by taking into account that k_ε represents private monetary costs while the costs σ_ε^2, for instance, indicate losses in physical harvest. This physical loss is carried forward from a subsidiary to the central company.

the following maximization problem:

$$\max_{s_i} E[\pi_i^{cc}] = \begin{cases} n \cdot \left(p_w s_i - \frac{1}{2}s_i^2 - w - E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2]\right) - k_\theta & \text{if } \frac{1}{n}k_\theta \le \sigma_\theta^2 \\ n \cdot \left(p_w s_i - \frac{1}{2}s_i^2 - w - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]\right) & \text{if } \frac{1}{n}k_\theta > \sigma_\theta^2 \end{cases}$$

with $x_i \equiv \widehat{x}_i + \theta$.[13] The solution is derived in the following lemma:

Lemma 7

The central company dictates subsidiary i to produce $s_i^* = p_w$ such that the central company's expected profit is given by

$$E[\pi^{cc}] = \begin{cases} n \cdot (\frac{1}{2}p_w^2 - w - \sigma_\varepsilon^2) - k_\theta & \text{if } \frac{1}{n}k_\theta \le \sigma_\theta^2 \\ n \cdot (\frac{1}{2}p_w^2 - w - \sigma_\varepsilon^2 - \sigma_\theta^2) & \text{if } \frac{1}{n}k_\theta > \sigma_\theta^2 \end{cases}$$

Proof. Straightforward. ■

Note that the wage payment w only has distributive effects between the subsidiaries and the central company. Addition of the central company's expected profit and aggregate wage payments $n \cdot w$, yields aggregate profit $E[\pi^h]$ in the hierarchical scenario as

$$E[\pi^h] \equiv E[\pi^{cc}] + n \cdot w = \begin{cases} n \cdot (\frac{1}{2}p_w^2 - \sigma_\varepsilon^2) - k_\theta & \text{if } \frac{1}{n}k_\theta \le \sigma_\theta^2 \\ n \cdot (\frac{1}{2}p_w^2 - \sigma_\varepsilon^2 - \sigma_\theta^2) & \text{if } \frac{1}{n}k_\theta > \sigma_\theta^2 \end{cases}$$

Comparing the efficiency of the hierarchical scenario with the cooperative scenario, we derive the following proposition:[14]

Proposition 3

A cooperative organization is more efficient than a hierarchical organization if and only if $k_\varepsilon < \sigma_\varepsilon^2$. Otherwise both organizational forms coincide regarding efficiency.

Proof. See Appendix. ■

The proposition shows that a hierarchical organization is less efficient than a cooperative organization if the learning costs to acquire idiosyncratic knowledge are low compared to the expected costs in case of not learning. In that case, the inefficiency stems from the fact that in a hierarchy, the individual subsidiary has

[13] Note that if $\frac{1}{n}k_\theta \le \sigma_\theta^2$, the central company has has paid k_θ and has distributed the information about θ to all subsidiaries. Similar to cases (i) and (ii) in Section 3.2, the realization of this variable is already incorporated in the optimal choice of the variable $x_i \equiv \widehat{x}_i + \theta$ such that $\widetilde{\theta}$ does not appear in the term $E[(\varepsilon_i - \widehat{x}_i)^2]$.

[14] In order to be able to compare both organisational forms, we have to derive expected *aggregate* profits in the cooperative scenario.

no incentive to produce optimally since the subsidiary's wage is independent of its profit. If $k_\varepsilon < \sigma_\varepsilon^2$ it would be optimally to invest k_ε in both the cooperative and the hierarchical scenario to learn about the individual characteristics ε_i and then adapt the choice of x_i accordingly. However, only the firms in the cooperative scenario invest in learning. Centralization leads to a situation where subsidiaries do not bear the costs of being inefficient.

4 Conclusion

In this paper, we compare the efficiency of three different organizational forms (market-, cooperative- and hierarchical organization) in a specific economic setting.

Worldwide, food processing is probably one of the most prominent industry which was historically dominated by cooperative organization. We can apply our theory to food processing as follows. Farmers create potential value by producing "raw" food such as cattle, grapes, milk, etc. Historically, these "intermediate" products were time-specific: they lost most if not all of their value unless they were processed within short time limits. Without modern refrigerating technology, milk, for example, has to be homogenized and/or pasteurized within hours. A dairy, for example, usually processes all milk from an entire region. In our model, the dairy represents the monopolist. The time specificity of agricultural products such as raw milk creates a hold up problem. This hold up problem could be solved through vertical integration. If the dairy vertically integrates into milk farming, however, it transforms independent, self-employed farmers into employees and thereby may destroy the incentives to acquire and apply idiosyncratic knowledge. How can the milk farmers remain self-employed while the hold up problem is eliminated through vertical integration? This "dilemma" was solved organizing the dairy as a cooperative jointly owned by the farmers.

Professional sports leagues such as the NFL, NBA, MLB and NHL are also organized as cooperatives. Sports leagues produce sports entertainment and excitement in a two-stage production process. Individual clubs invest in their respective teams, club facilities, stadiums, coaching staff etc. The output of these investments, however, is not a marketable product. A single team is more or less worthless. Each team needs at least one opponent. But single games are also not very attractive. What creates excitement and continuous attention by large audiences is a coordinated championship race. Creating such a championship race requires a league taking clubs' output and transforms it into a coordinated championship race. The complementary services of the league include the definition and enforcement of common rules, the scheduling of games, the marketing of the league (especially the sale of TV and merchandising rights), etc. Without these complementary services of the league, each club looses much of its value. This creates the classical hold up problem. One solution to this hold up problem is a vertically backward integrated league which owns all the participating clubs. Such an organizational structure creates a major problem. If all decisions are centralized, the league may lose its integrity. The fans probably want to see a championship race between independent clubs. Value maximization may require a combination of centralized decision-making at the league office (e.g. rule-making and enforcement, scheduling, etc.) and decentralized decision-making based on idiosyncratic knowledge at each club. Organizing the league as a cooperative of all participating clubs may solve the hold up problem and guarantee the necessary integrity and decentralization.

In our formal model, we have shown that idiosyncratic and general knowledge have important effects on the firms' investment behavior. According to the model, the firms' trade with the monopolist fails completely in a market solution because firms prefer their outside options. This replicates the well-known hold-up problem. The firms anticipate the monopolist's pressure after having specifically invested.

By comparing a market with a cooperative organization regarding efficiency, we have derived that it is crucial whether firms have an incentive to acquire general knowledge. In a cooperative, due to economies of scale the costs for detecting environmental characteristics are shared among all firms, whereas in market organization firms do not cooperate with each other such that every firm has to bear its own learning costs. As a consequence, if the learning costs to acquire general knowledge are relatively high, then a cooperative organization dominates a market organization. Moreover, if the difference in (expected) costs between a situation where a firm knows about general environmental characteristics and a situation where a firm has no knowledge about these characteristics is relatively high then a cooperative form is more efficient than a market organization. In addition, a relative high specificity of investment, a high exogenous world market price and a relative high number of firms also render a cooperative organization more efficient.

By comparing a hierarchical to a cooperative organization, we have shown that a hierarchy is less efficient if the learning costs to acquire idiosyncratic knowledge are relatively low compared to the expected costs in case of not learning. The inefficiency stems from the fact that in a hierarchy the individual subsidiary has no incentive to produce optimally. Centralization leads to a situation where subsidiaries do not bear the costs of being inefficient. We believe that in many industries cooperatives are formed in order to prevent these inefficiencies. In fact, we agree with Bonus (1986) that idiosyncratic knowledge might be an important ingredient affecting a firm's success. Dictating instructions by a central company in a hierarchy could destroy firm- or labour-specific knowledge based on experience.

A Appendix

A.1 Proof of Lemma 2

The monopolist maximizes its profit $\sum_{i=1}^{n}(p_w s_i - p_s s_i)$ by choosing the minimum price p_s such that firm i is just indifferent between this offer and its outside option, i.e. $p_s s_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2}s_i^2\right) - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] = p_v \cdot v_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2}s_i^2\right) - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]$. We solve this problem by introspection.[15] Note that both cost components cancel each other in the constraint and that we have normalized $p_v = 1$. Furthermore, since we consider symmetric firms, each firm produces the same amount s_i and v_i in equilibrium. As a consequence, the monopolist will set $p_s^*(s_i, v_i) = \frac{v_i}{s_i}$ it makes positive profits, i.e. if $p_w \geqslant p_s^* = \frac{v_i}{s_i}$. Otherwise (i.e. if $p_w < p_s^* = \frac{v_i}{s_i}$), the monopolist will set $p_s^*(s_i, v_i) = 0$.

A.2 Proof of Lemma 3

If the monopolist sets $p_s^* = \frac{v_i}{s_i}$ in period 3, firm i maximizes its expected profit by solving the maximization problem (1). The corresponding Lagrangian is given by

$$\mathcal{L} = p_s^* s_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2}s_i^2\right) - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] + \lambda_i[p_w s_i - p_s^* s_i]$$

where $\lambda_i \geq 0$ denotes the Lagrange multiplier for firm i and represents the marginal increase in profits by relaxing the constraint $p_w s_i - p_s^* s_i \geqslant 0$ infinitesimally. Plugging $p_s^* = \frac{v_i}{s_i}$ into the Lagrangian, we compute $\mathcal{L} = v_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2}s_i^2\right) - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] + \lambda_i[p_w s_i - v_i]$ and derive the following FOCs:

$$\frac{\partial \mathcal{L}}{\partial s_i} = -s_i + \lambda_i p_w = 0 \qquad \text{and} \qquad \frac{\partial \mathcal{L}}{\partial v_i} = 1 - \gamma v_i - \lambda_i = 0$$

By checking whether the constraint is binding or not, we distinguish two cases:

Case 1: Constraint is not binding, i.e. $p_w s_i - p_s^* s_i = p_w s_i - v_i > 0$. It follows: $\lambda = 0$. We compute firm i's optimal choice of s_i and v_i as

[15] We could also solve the problem by the Kuhn-Tucker approach.

$$(s_i^*, v_i^*) = \left(0, \frac{1}{\gamma}\right).$$

But $(s_i^*, v_i^*) = \left(0, \frac{1}{\gamma}\right)$ is not consistent with the constraint $p_w s_i - v_i > 0$. Therefore, this is not a solution.

Case 2: Constraint is binding, i.e. $p_w s_i - v_i = 0$. It follows: $\lambda \geqslant 0$. In this case, the monopolist receives zero profits. We compute firm i's optimal choice of s_i and v_i as

$$(s_i^*, v_i^*) = \left(\frac{p_w}{1+\gamma p_w^2}, \frac{p_w^2}{1+\gamma p_w^2}\right).$$

Plugging (s_i^*, v_i^*) into the firm's (expected) profit function $p_s^* s_i - \left(\frac{1}{2}\gamma v_i^2 + \frac{1}{2}s_i^2\right) - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]$, we derive firm i's expected profit in a market solution as

$$E[\widehat{\pi}_i^m] = \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2]$$

According to Lemma 1, the decision of firm i to invest in idiosyncratic and/or general knowledge depend on the learning costs $(k_\theta, k_\varepsilon)$ as well as the variances $(\sigma_\theta^2, \sigma_\varepsilon^2)$. Thus, firm i's expected profit in a market solution is given by

$$E[\widehat{\pi}_i^m] = \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] = \begin{cases} \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - \sigma_\theta^2 - \sigma_\varepsilon^2 & \text{if } k_\theta > \sigma_\theta^2 \text{ and } k_\varepsilon > \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - k_\theta - k_\varepsilon & \text{if } k_\theta \leqslant \sigma_\theta^2 \text{ and } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - \sigma_\theta^2 - k_\varepsilon & \text{if } k_\theta > \sigma_\theta^2 \text{ and } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - k_\theta - \sigma_\varepsilon^2 & \text{if } k_\theta \leqslant \sigma_\theta^2 \text{ and } k_\varepsilon > \sigma_\varepsilon^2 \end{cases}$$

A.3 Proof of Proposition 1

By comparing the two possible profits $E[\widehat{\pi}_i^m]$ in case (i) and $E[\pi_i^m]$ in case (ii), we derive that firm i favours its outside option if and only if

$$E[\widehat{\pi}_i^m] = \frac{1}{2}\frac{p_w^2}{1+\gamma p_w^2} - E[(\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] < \frac{1}{2}\frac{1}{\gamma} - E[\widetilde{\theta} + \widetilde{\varepsilon}_i - x_i)^2] = E[\pi_i^m]$$

$$\begin{aligned} &\Leftrightarrow \quad \frac{p_w^2}{1+\gamma p_w^2} < \frac{1}{\gamma} \\ &\Leftrightarrow \quad \gamma p_w^2 < 1 + \gamma p_w^2 \end{aligned}$$

This is true for all values of $\gamma > 1$. Thus, the outside option is always preferable for all firms.

A.4 Proof of Lemma 5

In period 2, firm i chooses s_i in order to maximize it's expected profit $E[\pi_i^c]$, anticipating the monopolist's price setting behavior in period 3. Thus, firm i solves the following maximization problem:

$$\max_{s_i} E[\pi_i^c] = \left(p_s^* s_i - \frac{1}{2}s_i^2 - E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2]\right)$$

Plugging $p_s^* = p_w - \frac{k_\theta}{n \cdot s_i}$ into the maximization problem and solving the FOCs, we derive the optimal choice $s_i^* = p_w$ with an expected profit of

$$E[\pi_i^c] = \frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - E[(\widetilde{\varepsilon}_i - \widehat{x}_i)^2] = \begin{cases} \frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - \sigma_\varepsilon^2 & \text{if } k_\varepsilon > \sigma_\varepsilon^2 \\ \frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - k_\varepsilon & \text{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \end{cases}$$

A.5 Proof of Proposition 2

It suffices to compare the expected profit of an arbitrary firm i. This approach is equivalent to comparing aggregate profits of all firms since firms are symmetric. Moreover, note that both the profit of the cooperative (in the cooperative scenario) as well as the profit of the monopolist (in the market scenario) is zero.

Case (i): $\frac{1}{n}k_\theta < k_\theta \leq \sigma_\theta^2$.

In this case it is profitable to invest k_θ in both the market scenario and the cooperative scenario. By comparing expected profits $E[\pi_i^c]$ of firm i in the cooperative scenario with the corresponding profit $E[\pi_i^m]$ in the market scenario, we derive the following inequality:

$$E[\pi_i^c] = (\frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - \min\{k_\varepsilon, \sigma_\varepsilon^2\}) > (\frac{1}{2}\frac{1}{\gamma} - k_\theta - \min\{k_\varepsilon, \sigma_\varepsilon^2\}) = E[\pi_i^m]$$

$$\iff k_\theta \frac{2(n-1)}{n} > \frac{1}{\gamma} - p_w^2$$

Case (ii): $\frac{1}{n}k_\theta \leq \sigma_\theta^2 < k_\theta$.

In this case, only the cooperative will invest k_θ in order to detect the value of θ but not the firms in the market scenario. Similarly, to case (i) we compare expected profits in both scenarios and derive:

$$E[\pi_i^c] = (\frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - \min\{k_\varepsilon, \sigma_\varepsilon^2\}) > (\frac{1}{2}\frac{1}{\gamma} - \sigma_\theta^2 - \min\{k_\varepsilon, \sigma_\varepsilon^2\}) = E[\pi_i^m]$$

On the left hand side we have firm i's expected profits in a cooperative as in case 1. On the right hand side firm i's expected profits differ from the expected profits in case 1 because $\sigma_\theta^2 < k_\theta$. The above inequality is rewritten as:

$$\underbrace{\sigma_\theta^2 - \frac{1}{n}k_\theta}_{\geq 0} > \frac{1}{2}\left[\frac{1}{\gamma} - p_w^2\right].$$

Case (iii): $\sigma_\theta^2 < \frac{1}{n}k_\theta < k_\theta$.

In this case, it is not profitable neither in the cooperative scenario nor the market scenario to invest k_θ. Again, we compare firm i's expected profit in both scenarios and derive:

$$E[\pi_i^c] = (\frac{1}{2}p_w^2 - \sigma_\theta^2 - \min\{k_\varepsilon, \sigma_\varepsilon^2\}) > (\frac{1}{2}\frac{1}{\gamma} - \sigma_\theta^2 - \min\{k_\varepsilon, \sigma_\varepsilon^2\}) = E[\pi_i^m]$$

Rearranging yields the following inequality:

$$p_w^2 > \frac{1}{\gamma}$$

A.6 Proof of Proposition 3

In order to compare the hierarchical scenario with the cooperative scenario, we have to derive expected *aggregate* profits in the cooperative scenario. Expected aggregate profits in the cooperative scenario are the sum of expected profits of the n firms plus the profit of the cooperative which is zero.

We have to distinguish two cases whether it is profitable to invest k_θ in order to detect θ or not: In case (i), it is profitable to invest k_θ in both the cooperative scenario and the hierarchical scenario, i.e. $\frac{1}{n}k_\theta \leq \sigma_\theta^2$. In case (ii), it is not profitable to invest k_θ in neither scenario, i.e. $\sigma_\theta^2 < \frac{1}{n}k_\theta$.

Case (i): $\frac{1}{n}k_\theta \leq \sigma_\theta^2$.

In this case, expected aggregate profit in the cooperative scenario denoted by $E[\pi^c]$ is given by:

$$E[\pi^c] \equiv n \cdot E[\pi_i^c] + \underbrace{\pi^{co}}_{=0} = \begin{cases} n \cdot (\frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - k_\varepsilon) & \text{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ n \cdot (\frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - \sigma_\varepsilon^2) & \text{if } k_\varepsilon > \sigma_\varepsilon^2 \end{cases}$$

Expected aggregate profit in the hierarchical scenario denoted by $E[\pi^h]$ is given by:

$$E[\pi^h] = n \cdot (\frac{1}{2}p_w^2 - \sigma_\varepsilon^2) - k_\theta$$

By comparing $E[\pi^c]$ with $E[\pi^h]$, we derive

$$n \cdot (\frac{1}{2}p_w^2 - \sigma_\varepsilon^2) - k_\theta = E[\pi^h] < E[\pi^c] = \begin{cases} n \cdot \left(\frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - k_\varepsilon\right) & \text{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \\ n \cdot \left(\frac{1}{2}p_w^2 - \frac{1}{n}k_\theta - \sigma_\varepsilon^2\right) & \text{if } k_\varepsilon > \sigma_\varepsilon^2 \end{cases}$$

$$\Leftrightarrow k_\varepsilon < \sigma_\varepsilon^2$$

If $k_\varepsilon < \sigma_\varepsilon^2$ then the cooperative organization is more efficient than the hierarchical organization. If $k_\varepsilon \geq \sigma_\varepsilon^2$ then both organizational forms coincide regarding efficiency.

Case (i): $\sigma_\theta^2 < \frac{1}{n}k_\theta$.

In this case, expected aggregate profit in the cooperative scenario denoted by $E[\widehat{\pi}^c]$ is given by:

$$E[\widehat{\pi}^c] = n \cdot E[\widehat{\pi}_i^c] + \underbrace{\pi^{co}}_{=0} = \begin{cases} n \cdot \left(\frac{1}{2}p_w^2 - \sigma_\theta^2 - \sigma_\varepsilon^2\right) & \text{if } k_\varepsilon > \sigma_\varepsilon^2 \\ n \cdot \left(\frac{1}{2}p_w^2 - \sigma_\theta^2 - k_\varepsilon\right) & \text{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \end{cases}$$

Expected aggregate profit in the hierarchical scenario denoted by $E[\pi^h]$ is given by:

$$E[\pi^h] = n \cdot (\frac{1}{2}p_w^2 - \sigma_\varepsilon^2 - \sigma_\theta^2)$$

By comparing $E[\widehat{\pi}_i^c]$ with $E[\pi^h]$, we derive

$$n \cdot (\frac{1}{2}p_w^2 - \sigma_\varepsilon^2 - \sigma_\theta^2) = E[\pi^h] < E[\widehat{\pi}_i^c] = \begin{cases} n \cdot \left(\frac{1}{2}p_w^2 - \sigma_\theta^2 - \sigma_\varepsilon^2\right) & \text{if } k_\varepsilon > \sigma_\varepsilon^2 \\ n \cdot \left(\frac{1}{2}p_w^2 - \sigma_\theta^2 - k_\varepsilon\right) & \text{if } k_\varepsilon \leqslant \sigma_\varepsilon^2 \end{cases}$$

$$\Leftrightarrow k_\varepsilon < \sigma_\varepsilon^2$$

We derive the same result as in case (i).

As a consequence, the cooperative organization dominates the hierarchical organization if $k_\varepsilon < \sigma_\varepsilon^2$, otherwise both organizational forms coincide.

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