Cognition and Incentives in Cooperatives

Anyan Wei and George Hendrikse[1]

Abstract. We extend the results of Feng and Hendrikse (2012) by investigating the relationship between cognition and incentives in cooperatives versus investor-owned firms (IOFs) in a multi-tasking principal-agent model. The principal chooses the incentive intensity as well as the precision of monitoring, while the agent chooses the activities. We establish that a cooperative is uniquely efficient when either the synergy between the upstream and downstream activities or the knowledgeability of the members regarding the cooperative enterprise is sufficiently high.

Keywords: Cognition, incentives, cooperative, governance, multi-tasking.

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'… most farmers cannot see any further than the farm gate and that directors of agricultural co-operatives … are production, rather than market oriented' (LeVay, 1983, p20)

1 Introduction

The institutional structure of production differs between countries and sectors (Bijman and Iliopoulos, 2014). For example, cooperatives have a market share of 40% in the European agricultural sector, varying from 65% in the Scandinavian countries to less than 20% in countries in South-Eastern Europe. Within the agricultural sector, the market share of cooperatives is 57% in dairy, 42% in fruits and vegetables, 36% in sugar and 4% in sheep meats. Governance structures differ also in terms of resilience. For example, Co-operatives UK (2021) reports that the number of cooperatives operating across the UK grew by 1.2% between 2020 and 2021. The overall message of these numbers is that cooperatives have apparently features that make them survive, or even create superior value, in competition with other enterprises. This article formulates a model to determine the circumstances when a cooperative creates more value than other enterprises. To be more specific, we investigate how the provision of incentives and the allocation of cognitive units in a cooperative may create more value than enterprises owned by investors.

A cooperative enterprise is owned by a society of members, where members have an ownership relationship as well as a user relationship, either as a supplier or buyer, with their cooperative enterprise. Advantages and disadvantages of the cooperative governance structure reside either in the ties between the members and the cooperative enterprise, or in the ties between members in the society of members. Examples of advantages due to the member-enterprise relationship are the elimination of double marginalization, the assurance of access, countervailing power, and member services. Advantages due to the ties between the members are learning and coordination. Disadvantages of cooperatives are free riding between the members and the misalignment of the interests between the members and the management of the cooperative enterprise. This is in contrast to an IOF where the interests of the investors are most important, and may result in the behavior of the cooperative enterprise being different than the behavior of an IOF.

Running a farm is also a complicated activity. Knowledge is required regarding land, seeds, animals, machinery, accounting, information and communication technologies, robotics, and other enterprises adjacent to it in the supply chain. A farmer may acquire this knowledge by education, consulting colleagues, buying advice, or becoming a member of a cooperative in which the society of members may provide or organize the information. Co-operatives may be valuable in such an environment. LeVay (1983, p33) observes that 'It may be that co-operatives are a good means for disseminating information and for feeding back to producers the relevant messages in order best to match supply with demand.' However, LeVay (1983, p20) states also that 'As for the directors of agricultural co-operatives … doubts persist as to their competence persists in the literature'. In such cases, many of the strategies of the cooperative tend to be less effective, as farmers are asked to make decisions, or formulate directions, about projects without having sufficient expertise. Similar statements can of course be formulated regarding the management of an upstream or downstream enterprise and the competence of its owners/management regarding issues at another stage of production. This is reflected by Cook (1994, p56) when he writes regarding the focus in different enterprises that 'Cooperative management … must concentrate more planning efforts on developing entrepreneurial and operating abilities rather than on portfolio-related objectives. This places a premium on the technical-operations, people-oriented resource allocation manager than on the financial-portfolio, diversification-oriented manager.' These observations ask for a comparative institutional analysis of cooperatives and IOFs from a cognitive perspective in order to determine the circumstances when cooperatives create more value than other types of businesses.

Insights regarding organizations have been formulated mainly from a conflicting interests perspective during the last 50 years. This has generated a wealth of insights regarding the efficient resolution of incentive issues (Milgrom and Roberts 1992; Bolton and Dewatripont 2005; Gibbons and Roberts 2012). An important assumption in this literature is that individuals have unlimited cognitive capabilities to address the issues they are facing. However, the cognitive capacities of people are often not sufficient to grasp all the complexities of a problem due to genetic endowments, education, and experiences. This has been recognized in the scientific literature a long time ago (Simon 1947 and 1971; Cyert and March 1963). Arrow (1974) argues even that bounded cognition is the reason for the existence of organizations because arranging people in a smart way allows the organization to do more than what they can achieve individually. Recently, Kumbure et al. (2020) argue that industrial performance resides in cognitive abilities. Cao et al. (2020) and Helfat and Peteraf (2015) suggest that cognitive ability may help to explain why some top managers have more effective abilities than others to anticipate, interpret, and respond to the demands of an evolving environment. Other recent studies show that cognitive ability is an important factor in the successful decision-making process and the effective organizational performance of entrepreneurs. This applies especially in dynamic environments (Bajwa et al. 2017).

The lack of an appropriate game theoretic equilibrium concept regarding limited cognition has hampered the development of insights regarding organizations from a cognitive perspective. However, recent advances in the formulation of alternative equilibrium concepts (Arad and Rubinstein 2019; Goeree and Louis 2021) are triggering a renewed interest in formulating insights from a limited cognition perspective. Examples are Dessein and Santos (2021) and Gibbons et al. (2021). This article is in line with Milgrom and Roberts (1992) and Dessein and Santos (2021). It investigates the impact of the cost of attention on the value creation of cooperatives versus investor-owned firms in a multi-tasking principal-agent model (Milgrom and Roberts 1991; Feng and Hendrikse 2012). The standard multi-tasking principal-agent model focuses on the incentive intensity. Our model chooses the incentive intensity as well as the precision of monitoring.[2] The choice of the allocation of cognitive units to the precision of monitoring determines in our model the uncertainty of the environment.

The difference between a cooperative and an IOF is driven in our model by the assumption that a party in a supply chain is more knowledgeable of the production activities at the own stage of production. It entails that the owners of a cooperative have a better understanding of the production activities at their stage of production than at the stage of the cooperative enterprise. The implications of this differential endowment of cognitive abilities for the activities of a cooperative versus an IOF are determined by addressing the following questions: How do cooperatives and IOFs react to external risks? How does the monitoring intensity affect the incentive intensity? In which circumstances is a cooperative the unique efficient governance structure?

The article is organized as follows. Section 2 formulates the model. Section 3 determines the equilibrium incentive and monitoring intensity. Section 4 formulates the equilibrium analysis in terms of the comparative statics results (4.1) and efficiency (4.2). Section 5 concludes.

2 Model

[2] Other approaches regarding the analysis of the efficiency of cooperatives from a bounded cognition perspective are screening errors (Hendrikse, 1998), bias (Deng and Hendrikse, 2014), inaccurate recognition of the environment (Hendrikse, 2021), partitioning (Hendrikse, 2021), and local neighborhoods (Deng and Hendrikse, 2022).

Consider an upstream (u) and a downstream (d) party. Define a_{ij} as the activity level by party i at stage j, where $i, j \in \{u, d\}$. The output level by party i at stage j is $z_{ij} = a_{ij} + x_j$, where x_j reflects the random events regarding the output z_{ij} that cannot be controlled by party i. The compensation contract specifies the wage w paid as a linear function of performance measure p, i.e.

$$w = \alpha + \beta p,$$

where α stands for the fixed salary and β for the bonus rate (incentive intensity). The technology of performance measurement takes the form

$$p = g_u z_{iu} + g_d z_{id},$$

where g_u and g_d are the performance parameters for upstream and downstream output respectively. The principal's payoff (π) is the difference between the agent's total contribution to the value of the firm (y), the wage paid (w) ,and the monitoring cost ($M(V)$):

$$\pi = y - w - M(V).$$

The monitoring cost $M(V)$ is defined as the minimum amount that must be spent by the principal to achieve a variance level as low as V (Milgrom and Roberts 1992) and is specified as

$$M_i(V) = \frac{\omega_{iu}}{V_u} + \frac{\omega_{id}}{V_d},$$

in which $\omega_{ij} \geqslant 0$stands for the cognition cost of party i at stage j. (Cognition cost is interpreted as the inverse of cognitive ability.) The payoff of agent i is the difference between the wage received, the cost of the actions taken and the risk premium:

$$U = w - c(a_{iu}, a_{id}) - \frac{1}{2} r Var(w),$$

where r is defined as the exogenous risk aversion rate. The cost function is based on Dixit (2002):

$$c = \frac{1}{2} a_{iu}^2 + k a_{iu} a_{id} + \frac{1}{2} a_{id}^2.$$

The parameter k captures interdependencies between the upstream and downstream activities in the production chain. There are no interdependencies when $k=0$. When $0<k<1$, the two tasks are substitutes, i.e., an increase in a_{iu} increases the marginal cost of activity in a_{id}, therefore enhancing the marginal incentive payment for greater output of a_{iu} (but drawing activity away from a_{id}). When $-1<k<0$, the two tasks are complements, implying that the interaction between the two tasks strengthens incentives for both.

The total output of the firm generated by the agent's activities is denoted by y. Denote the marginal value added of activity a_{iu} and a_{id} by f_u and f_d. The production function is

$$y=f_u z_{iu}+f_d z_{id}+\varepsilon,$$

where ε is a stochastic variable with an expected value of zero, representing the noise in the production process that is beyond the agent's control.

Our analysis is focused on comparing the value created by a supply chain consisting of a cooperative with upstream ownership with a supply chain where each stage of production is owned by a separate investor. A distinguishing feature of the cooperative enterprise is that it has no public listing, which is reflected by taking $g_d=0$ in the performance measurement technology (Feng and Hendrikse 2012). The other production function and performance measurement parameters of the cooperative are $f_u>0, f_d>0, g_u>0$. The downstream IOF is characterized by the parameters $f_u=0, f_d>0, g_u=0, g_d>0$.

The sequence of decisions is as follows. The principal chooses simultaneously the incentive and monitoring intensity in the first stage of the game. The agent chooses whether to accept or reject the contract in the second stage of the game. In the third stage of the game, the agent chooses the level of each activity.

3 Equilibrium

The Nash equilibrium of the game is determined by using the method of backward induction. We start therefore at the third stage of the game. The agent chooses his level of activities to maximize his own expected utility, i.e., $\max_{a_{iu}, a_{id}} E(U)$, where:

$$E(U)=E\left[w-c(a_{iu},a_{id})-\frac{1}{2}rVar(w)\right]=\alpha+\beta(g_u a_{iu}+g_d a_{id})-\left(\frac{1}{2}a_{iu}^2+k\,a_{iu}a_{id}+\frac{1}{2}a_{id}^2\right)-\frac{1}{2}r\beta^2(V_u+V_d),$$

where V_u is $g_u^2 Var(x_u)$ and V_d is $g_d^2 Var(x_d)$, and V_u and V_d are assumed to be independent.[3]

Under the first-order condition with respect to a_{iu} and a_{id}, we have the agent's optimal activities $a_{iu}^{¿}(\beta)=\frac{\beta}{1-k^2}(g_u-k\,g_d)$ and $a_{id}^{¿}(\beta)=\frac{\beta}{1-k^2}(g_d-k\,g_u)$. Anticipating these choices by the agent in the final stage of the game, the principal chooses the optimal $\beta^{¿}$, $V_u^{¿}$ and $V_d^{¿}$ to maximize the total surplus, that is $\max_{\beta,V_u \wedge V_d} E(\pi+U)$. This results in the reaction functions regarding the incentive intensity and the monitoring intensities. The incentive intensity principle, i.e. the reaction function of β, is $\beta^*(V_u, V_d)=(f_u g_u-kf_d g_u)/((1-k^2)r(V_u+V_d)+g_u^2)$. Notice that it is negatively related to the variance, i.e. the principal will tend to set a relatively large basic salary combined with a small bonus rate when the variance is high in order to limit the expose of the agent to risk. The monitoring intensity principles, i.e. the reaction functions of $V_u$and V_d, are $V_u^* = \frac{1}{\beta}\sqrt{\frac{2\omega_{uu}}{r}}$ and $V_d^* ¿ \frac{1}{\beta}\sqrt{\frac{2\omega_{ud}}{r}}$. These reaction functions are depicted in figure 1, where $W = \sqrt{\omega_{uu}}+\sqrt{\omega_{ud}}$. The shape of the downward sloping line is due to the second-order derivative being positive.

[3] We have analyzed a correlation parameter regarding the variances, but the results remain qualitatively the same. Additionally, this parameter would play the same role as the synergy parameter k, but with more complicated expressions. So we assume that the variances are independent.

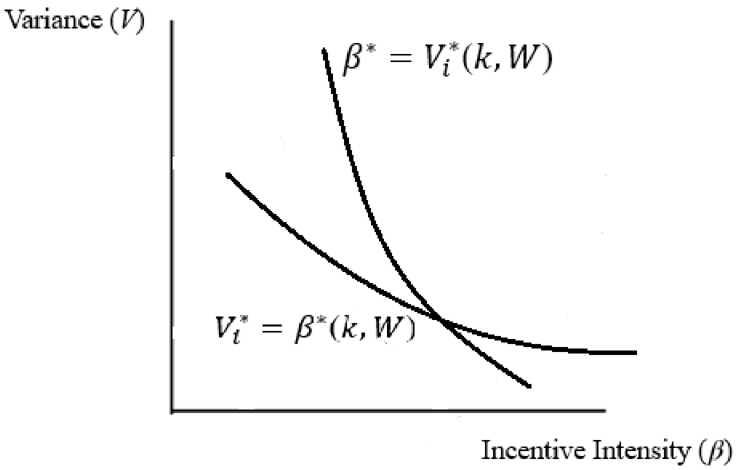

Figure 1. Incentive intensity principle and monitoring intensity principle

The intersection of these reaction functions results in the equilibrium $\beta^{¿*¿¿}$, $V_u^{¿*¿¿}$ and $V_d^{¿*¿¿}$ of a cooperative, and is formulated in proposition 1.

Proposition 1. *The optimal bonus rate and desired levels of the variances are*

$$\beta^{¿*¿=\frac{1}{g_u^2}\left[\left(f_u g_u - k f_d g_u\right) - \sqrt{2r}\left(1-k^2\right)W\right]¿};$$

$$V_u^{¿*¿=\sqrt{\frac{2\omega_{uu}}{r}}g_u^2/\left[\left(f_u g_u - k f_d g_u\right) - \sqrt{2r}\left(1-k^2\right)W\right]¿};$$

$$V_d^{¿*¿=\sqrt{\frac{2\omega_{ud}}{r}}g_u^2/\left[\left(f_u g_u - k f_d g_u\right) - \sqrt{2r}\left(1-k^2\right)W\right]¿},$$

with $W < \frac{f_u g_u - k f_d g_u}{\sqrt{2r}\left(1-k^2\right)}$ *(due to* $\beta^{¿}, V_u^{¿} \wedge V_d^{¿} > 0 ¿$.

The total surplus for a cooperative is

$$E\left(\pi + U\right) = \left(\frac{f_u - k f_d}{\sqrt{2\left(1-k^2\right)}} - \frac{\sqrt{r\left(1-k^2\right)}}{g_u}W\right)^2 \quad (?.1)$$

The total surplus decreases when cognition cost rate ω_{uu} and ω_{ud} increase. The maximum value $E(\pi+U)=\frac{(f_u-kf_d)^2}{2(1-k^2)}$ is obtained when ω_{uu} and ω_{ud} are equal to 0, i.e. the introduction of the variance reduces the overall total surplus. Note that the total surplus function only makes sense when $W<\frac{f_u g_u - k f_d g_u}{\sqrt{2r}(1-k^2)}$. If the total variance is too large to handle, the agent will not take any activity, resulting in an overall output and cost of 0.

4 Equilibrium Analysis

4.1 Comparative statics[4]

The impact of changes in ω_{iu}, ω_{id} and k on the payoff maximizing bonus rate $\beta^{¿*¿¿}$ and variance $V^{¿*¿¿}$ will be determined. The appendix shows that an increase in ω_{iu}, ω_{id} and k will decrease the payoff maximizing bonus rate $\beta^{¿*¿¿}$.

Proposition 2. *An increase in the cognition cost rate ω_{iu}, ω_{id} or the interdependency parameter k will generate a lower level of $\beta^{¿*¿¿}$, i.e.*

$$\partial\frac{\beta^{¿*¿}}{\partial k}<0,\partial\frac{\beta^{¿*¿}}{\partial\omega_{iu}}<0,\partial\frac{\beta^{¿*¿}}{\partial\omega_{id}}<0¿¿¿.$$

It entails that markets with low supply chain synergies / interdependencies, i.e. a high level of k, and low knowledgeability of the members of the cooperative, i.e. the cognition cost parameters are high, are expected to have a relatively low incentive intensity. In the reaction functions above, we can see that a decrease in chain interdependency leads directly to a decrease in incentive intensity; the mechanism of the cognition cost parameter is a little more complex: a higher cognition cost parameter first generates a higher desired variance level, then leads the incentive intensity to decrease.

[4] All proofs in this section can be found in the Appendix.

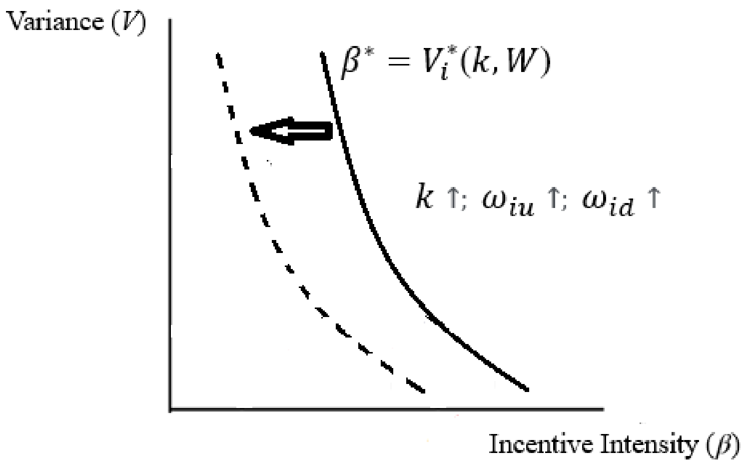

Figure 2. Payoff maximizing incentive intensity

Similarly, the comparative statics results regarding the monitoring intensity are formulated in Proposition 3.

Proposition 3. *An increase in the cognition cost rate* ω_{iu}, ω_{id} *or the interdependency parameter* k *will generate a higher level of* $V^{¿*¿¿}$*, i.e.:*

$$\partial \frac{V^{¿*¿}}{\partial k} > 0, \partial \frac{V^{¿*¿}}{\partial \omega_{iu}} > 0, \partial \frac{V^{¿*¿}}{\partial \omega_{id}} > 0. ¿¿¿$$

Figure 3 depicts proposition 3. The payoff maximizing variance level increases when the cognition cost parameters increase or the chain interdependencies decrease. Similarly, this causal mechanism can be obtained in the reaction functions: a reduction in chain interdependency first reduces the incentive intensity and therefore leads to an increase in the desired variance level; while the effect of the cognition cost parameter is intuitive, with lower knowledgeability, the desired variance level increases.

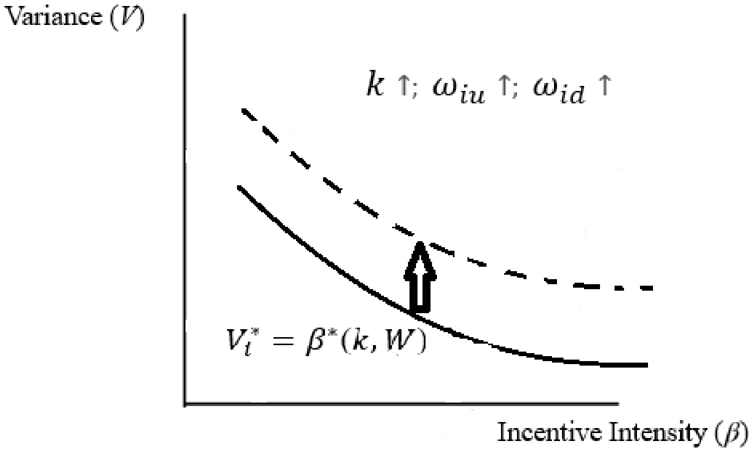

Figure 3. Payoff maximizing monitoring intensity

The impact of a change in ω_{iu}, ω_{id} or k on the equilibrium incentive intensity and variance is depicted in figure 4. The two solid curves depict the incentive and monitoring intensity principles. The intersection of the dotted curves shows the comparative statics effect of both principles. The overall equilibrium result due to the interaction between the incentive intensity and monitoring intensity principles shows that when the chain interdependency becomes lower (k increases) or the cognitive ability drops (ω_{iu}/ω_{id} increases),i.e. the incentive intensity decreases and the desired variance level increases, with these two effects reinforcing each other. The equilibrium shifts from point A to point C due to the incentive effect, and from C to B due to the monitoring effect (It can also follow the sequence from A to D to B). This is actually a combination of the two causal effects mentioned above. A low chain interdependency directly reduces the incentive intensity, leading to an increase in the desired variance level (which is negatively correlated with the incentive intensity), thus pushing the incentive intensity to decrease further. In other words, when principals observe a reduction in the chain synergy (meaning a reduction in the externality of upstream or downstream activities), they will reduce the incentives for agents to act by, for example, reducing the bonus rate. Notice also that a reduction in the bonus rate will lead to a reduction in the intensity of the principals' monitoring of the agents' actions, resulting in an increase in the variance of the agents' actions. Finally, an increase in the variance of the agents' actions will make it more difficult for the principals to distinguish whether the agents are working diligently or negligently, thus further reducing the bonus rate.

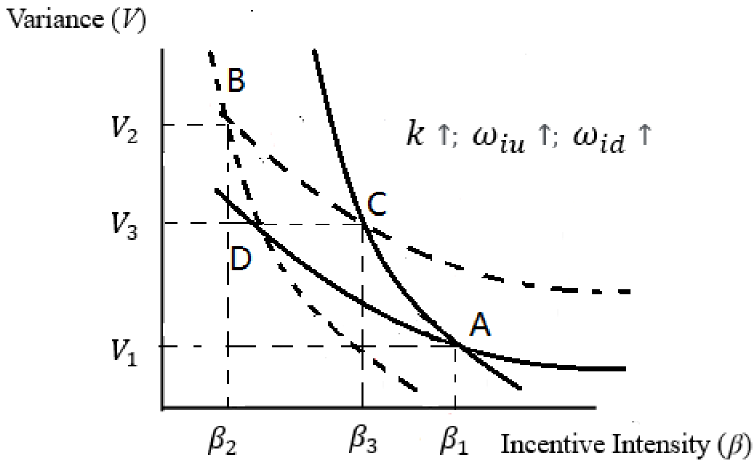

Figure 4. Comparative statics

The comparative statics results regarding the total surplus of the cooperative are formulated in proposition 4.

Proposition 4. *The impact of a change in* ω_{iu}, ω_{id} *or* k *on the equilibrium surplus of the cooperative is*

$$\frac{\partial E(\pi+U)}{\partial k}<0,\frac{\partial E(\pi+U)}{\partial \omega_{iu}}<0,\frac{\partial E(\pi+U)}{\partial \omega_{id}}<0.$$

4.2 Efficiency

The efficient governance structure is determined by comparing the total surplus of the cooperative, which is formulated in expression (1), with the sum of the surplus of an upstream and downstream IOF. The surplus of each IOF is[5]

$$E(\pi+U)=\left(\frac{f_u}{\sqrt{2(1-k^2)}}-\frac{\sqrt{r(1-k^2)}}{g_u}\sqrt{\omega_{uu}}\right)^2 ¿?.2)$$

[5] The figures regarding the surplus of each governance structure are presented in the Appendix.

with $\sqrt{\omega_{uu}} < \frac{f_u g_u}{\sqrt{2r}\left(1-k^2\right)}$, and

$$E\left(\pi+U\right)=\left(\frac{f_d}{\sqrt{2\left(1-k^2\right)}}-\frac{\sqrt{r\left(1-k^2\right)}}{g_d}\sqrt{\omega_{dd}}\right)^2 \quad (?.3)$$

with $\sqrt{\omega_{dd}} < \frac{f_d g_d}{\sqrt{2r}\left(1-k^2\right)}$.

We have calculated the closed-form result, but it is too lengthy to lead us to any meaningful and interesting conclusion in general.[6] We decided to look at two boundary cases. Consider first the case when the IOFs have the highest level of cognitive abilities to reduce the variance to 0 without any monitoring cost ($w_{uu}=w_{dd}=0, \omega_{ud}>0$). This simplifies the comparison to

$$\left(\frac{f_u-kf_d}{\sqrt{2\left(1-k^2\right)}}-\frac{\sqrt{r\left(1-k^2\right)}}{g_u}\sqrt{\omega_{ud}}\right)^2-\frac{f_u^2}{2\left(1-k^2\right)}-\frac{f_d^2}{2\left(1-k^2\right)} \quad (?.4)$$

A cooperative is efficient when the value of function (?.4) is larger than 0, i.e.

$$E\left(\pi+U\right)=\frac{\left(f_u-kf_d\right)^2-f_u^2-f_d^2}{2\left(1-k^2\right)}-\frac{\sqrt{2r}\left(f_u-kf_d\right)}{g_u}\sqrt{\omega_{ud}}+\frac{r\left(1-k^2\right)}{g_u^2}\omega_{ud}>0.$$

The only solution is

$$\sqrt{\omega_{ud}}<\frac{g_u}{\sqrt{2r}\left(1-k^2\right)}\left[\left(f_u-kf_d\right)-\sqrt{f_u^2+f_d^2}\right] \text{ when } k<\frac{f_u-\sqrt{f_u^2+f_d^2}}{f_d}$$

(to ensure the non-negativity of W).

Figure 5 below depicts the relationship between the cognitive ability of the cooperatives and the interdependency parameter.

[6] The closed form result is presented in the Appendix.

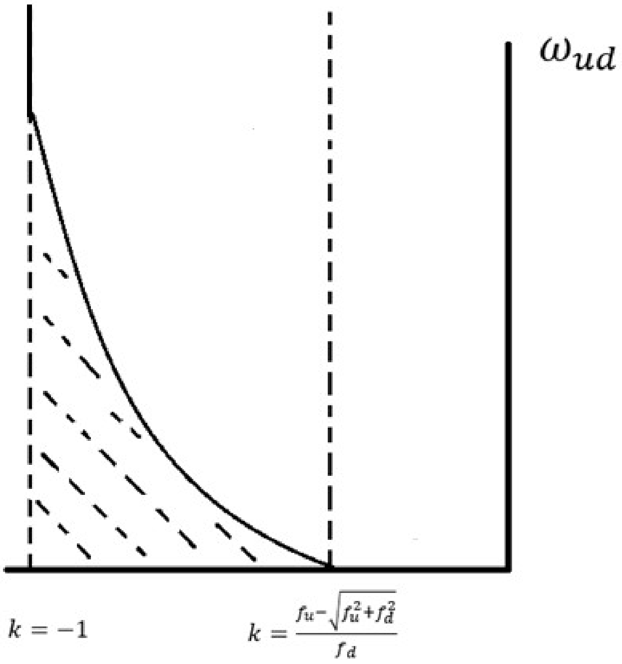

Figure 5. Efficient governance structure when IOFs have the highest cognitive abilities

The cooperative is efficient for the parameter values in the shaded area. The boundary $\sqrt{\omega_{ud}} = \frac{g_u}{\sqrt{2r}\left(1-k^2\right)}\left[\left(f_u - k f_d\right) - \sqrt{f_u^2 + f_d^2}\right]$ is negatively related to the risk aversion rate, but positively related to the upstream marginal performance. It entails that if the agent has a higher risk resistance (or a lower risk sensitivity) and the principal's evaluation for the agent's upstream performance increases, the cooperative can be efficient in a wider range. Notice that Feng and Hendrikse (2012) is a specific case of our model. If we set $\omega_{ud} = 0$, then the efficient zone becomes the vertical line segment between $k = \frac{f_u - \sqrt{f_u^2 + f_d^2}}{f_d}$ and $k = -1$.

Consider next the case when the IOFs have very low cognitive abilities, i.e. they fail to deal with any external variance and the total surplus generated is 0. The comparison simplifies to

$$\left(\frac{f_u-kf_d}{\sqrt{2\left(1-k^2\right)}}-\frac{\sqrt{r\left(1-k^2\right)}}{g_u}W\right)^2>0$$. It follows directly that the cooperative is efficient for any ω_{ud} which satisfies

$$0<\sqrt{\omega_{ud}}<\frac{f_u g_u-kf_d g_u}{\sqrt{2r}\left(1-k^2\right)}-\sqrt{\omega_{uu}}.$$

The shaded area in Figure 6 illustrates this result. It shows that it is not necessary to have a negative value of k to make a cooperative efficient. This indicates that the two stages of production covered by the cooperative (the farmers and the processor) can deal with the external risk collaboratively and have a cognition benefit by channels such as information sharing, in such a way that the cooperative can perform better than the IOFs. In the Appendix, we provide various numerical examples to illustrate this possibility.

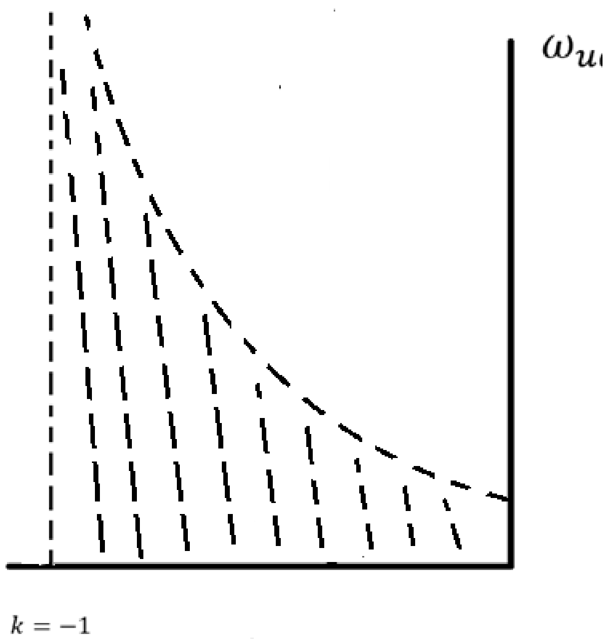

Figure 6. Efficient governance structure when IOFs have the lowest cognitive abilities

Proposition 5. *A cooperative is efficient when*

$$\sqrt{\omega_{uu}}+\sqrt{\omega_{ud}}<\frac{g_u}{\sqrt{2r}\left(1-k^2\right)}\left[\left(f_u-kf_d\right)-\sqrt{f_u^2+f_d^2}\right] with\ -1<¿$$

$$k<\frac{f_u-\sqrt{f_u^2+f_d^2}}{f_d}.$$

This proposition establishes that the scope for cooperatives as an efficient organizational form is expanded when cognitive considerations are taken into account in addition to incentive considerations. The reason is that the unique features of cooperatives allow for the development of policies to create additional value. Our model expresses that the creation of value from a cognitive perspective resides on the one hand in the ties between the members in the society of members and on the other hand in the intense, often day to day, relationship between each member and the joint enterprise at an adjacent stage in the production chain. The former is reflected in the parameters ω_{uu} and ω_{ud}, while the latter is reflected in the parameter *k*.

5 Conclusion and further research

This article has developed a multi-tasking principal–agent model to determine the circumstances when a cooperative creates more value than IOFs. It is established that the interdependency between upstream and downstream activities as well as the cognitive abilities of the members are important sources to make the cooperative the unique efficient governance structure. By extending the efficient boundary of the cooperative business, this article contributes to the literature explaining why cooperatives exist and blossom in many industries.

There are various possibilities for further research. We formulate two possibilities. First, various empirical studies report the efficiency of cooperatives. For example, Abate et al. (2014) study the impact of agricultural cooperatives on smallholders' technical efficiency empirically and find cooperatives beneficial for the supply of support services that significantly contribute to the technical efficiency of the membership. D'Amato et al. (2021) and Silva and Morello (2021) document efficiency advantage of cooperatives in Italy and Brazil respectively. Our model specifies two main parameters which are responsible for the efficiency of a cooperative. However, the sources of these parameters have to be studied, which will facilitate the formulation of managerial policies to realize the creation of value. Many sources of the synergy parameter have been identified in the literature, such as coordination, elimination of double marginalization, and assurance of access, but the sources of cognitive (dis)advantages of cooperatives seem to be underdeveloped.

Second, the cooperative is modelled as a relationship between one principal and one agent. The feature of one principal is a start to reflect the society of members, but it is silent on the interactions, and their cognitive consequences, between all the members within the society of members. This depends on the specific supply chain as well as the specific stage in the supply chain which is considered. For example, Gong et al. (2019) investigate technical efficiency in crop production in China. They establish that core members of cooperatives show the highest technical efficiency, while the nonmembers have the lowest technical efficiency. They further infer that the cooperative membership may grant the members the accessibility to learn more advanced technology and take advantage of productivity-enhancing practices. Sources of learning may be the society of members (Manouchehrabadi et al. 2021), or the provision of extension services by the government. Additionally, the organization of the network ties (Beaman et al. 2021; Garcia-Jimeno et al. 2022) between the members in the society of members may create value when the cooperative becomes involved in the organization of these extension services.

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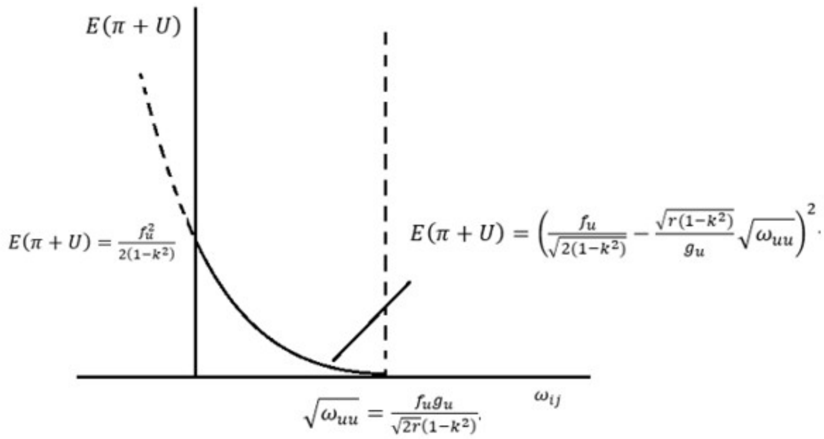
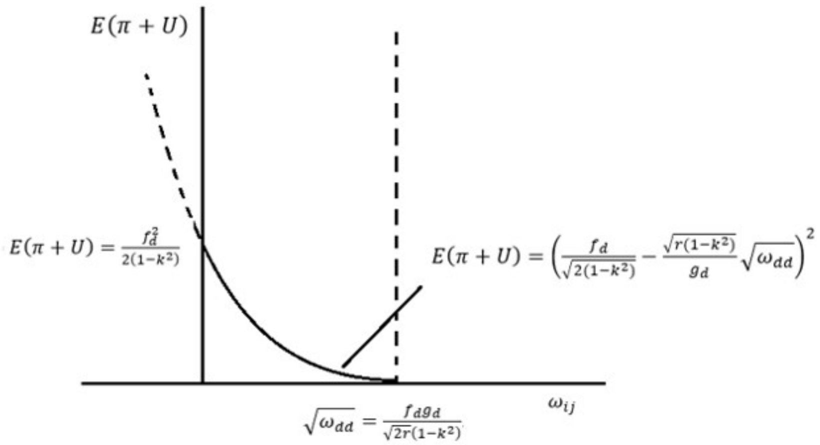
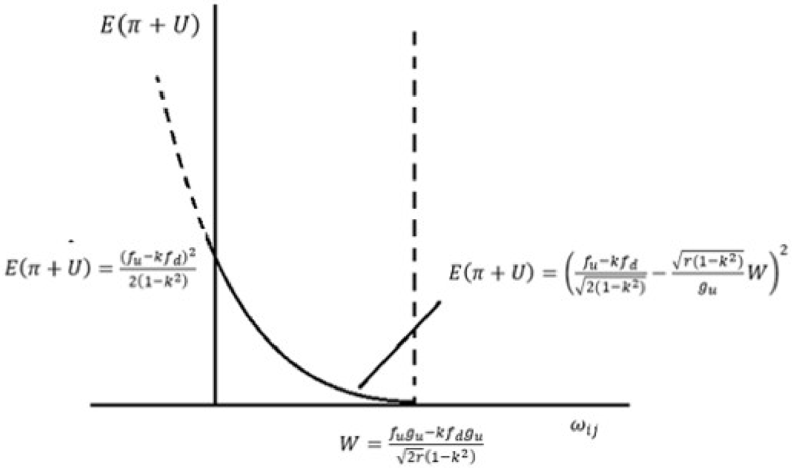
Appendix

A. Total surplus figures

The figures representing the total surplus of the upstream IOF, the downstream IOF and the cooperative respectively:







B. Proofs of comparative statics results

Denote $\left[\left(f_u g_u - k f_d g_u\right) - \sqrt{2r}\left(1-k^2\right) W\right]$ as F¿ 0.

$$\frac{\partial \beta^{¿}}{\partial k} = \frac{1}{g_u^2}\left(2\sqrt{2r}\,k\,W - f_d\,g_u\right) < 0; \frac{\partial \beta^{¿}}{\partial \omega_{ii}} = \frac{1}{g_u^2}\sqrt{2r}\left(1-k^2\right) < 0;$$

$$\frac{\partial V_u^{¿}}{\partial k} = \frac{-\sqrt{\frac{2\omega_{uu}}{r}}\,g_u^2\left(2\sqrt{2r}\,k\,W - f_d\,g_u\right)}{F^2} > 0; \frac{\partial V_u^{¿}}{\partial \omega_{iu}} = \frac{\left[F\sqrt{\frac{1}{2r\,\omega_{iu}}}\,g_u^2 + g_u^2\left(1-k^2\right)\right]}{F^2} > 0;$$

$$\frac{\partial V_u^{¿}}{\partial \omega_{id}} = \sqrt{\frac{r}{2\omega_{id}}}\left(1-k^2\right)/F^2 > 0;$$

So as

$$\frac{\partial V_d^{¿}}{\partial k} > 0, \frac{\partial V_d^{¿}}{\partial \omega_{iu}} > 0, \frac{\partial V_d^{¿}}{\partial \omega_{id}} > 0;$$

In terms of $\frac{\partial E(\pi+U)}{\partial k}$, for $-1<k<0$ and when k is increasing, $(f_u - k f_d)$ is decreasing, $\sqrt{2(1-k^2)}$ is increasing, $\sqrt{r(1-k^2)}$ is increasing, so the overall effect is decreasing, $\frac{\partial E(\pi+U)}{\partial k}<0$; denote $\left(\frac{f_u-k f_d}{\sqrt{2(1-k^2)}}-\frac{\sqrt{r(1-k^2)}}{g_u}W\right)$ as T,

$$\frac{\partial E(\pi+U)}{\partial \omega_{iu}}=\frac{-\sqrt{\frac{r(1-k^2)}{\omega_{iu}}}}{g_u}T<0,\ \frac{\partial E(\pi+U)}{\partial \omega_{id}}=\frac{-\sqrt{\frac{r(1-k^2)}{\omega_{id}}}}{g_u}T<0.$$

C. Efficiency numerical illustrations

We would like to investigate under which condition the difference between the cooperative's total surplus to the sum of the two IOFs can be positive (indicating the cooperative is efficient). Here we denote *H* as the difference, and H has the form below

$$H=\left(\frac{f_u-k f_d}{\sqrt{2(1-k^2)}}-\frac{\sqrt{r(1-k^2)}}{g_u}\left(\sqrt{\omega_{uu}}+\sqrt{\omega_{ud}}\right)\right)^2-\left(\frac{f_u}{\sqrt{2(1-k^2)}}-\frac{\sqrt{r(1-k^2)}}{g_u}\sqrt{\omega_{uu}}\right)^2-\left(\frac{f_d}{\sqrt{2(1-k^2)}}-\frac{\sqrt{r(1}{g}\right.$$

To solve for $H>0$, we will have a function describing the relations between ω_{ud} and k.

First, we directly calculate the above function and report the result from Matlab. $\omega_{ud}(k)$ should be in the following interval to make the cooperative efficient:

$$\left(\frac{-\sigma_2-ab+\sqrt{2}ab+abk-\sigma_1}{\sigma_3},\text{¿}\frac{-\sigma_2-ab-\sqrt{2}ab+abk+\sigma_1}{\sigma_3}\right)$$

$where\ \sigma_1=\sqrt{2}w\sqrt{2-2k^2}\sigma_4;\sigma_2=w\sqrt{2-2k^2}\sigma_4;\sigma_3=\sqrt{2-2k^2}\sigma_4$ $;\sigma_4=\sqrt{-r(k^2-1)}$.

The explicit result is too lengthy to analyze. Two numerical examples are presented to illustrate various insights. The first example demonstrates that stronger cognition capacity of the upstream party offsets the negative effects of lower chain interdependency, allowing cooperatives to outperform the IOFs; the second example shows that when cognitive capacity is low, stronger interdependency within the industry still allows cooperatives to be more efficient.

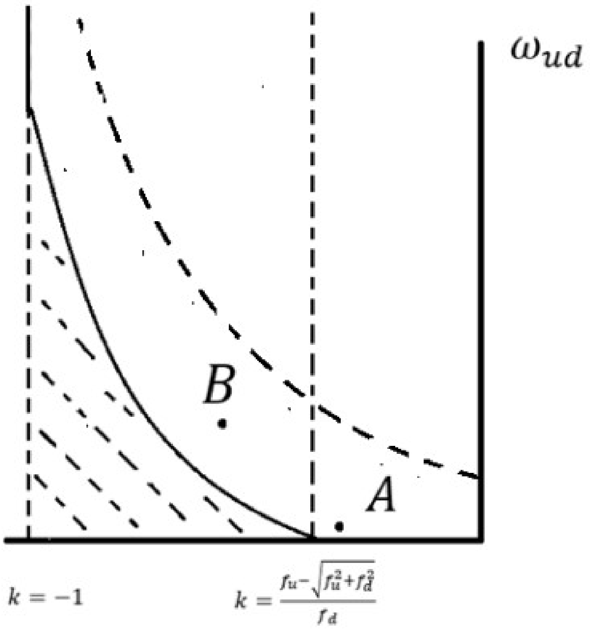


Figure A2. Two examples of how cognition capacity and chain interdependency can complement each other and make the cooperative more effective

We set values for variables for both examples as follows:

$$f_u = f_d = 20;\, g_u = g_d = 1;\, \omega_{uu} = \omega_{dd} = 4;\, r = 0.5,\, \frac{f_u - \sqrt{f_u^2 + f_d^2}}{f_d} = 1 - \sqrt{2}$$

.

For point A, we set $\omega_{ud} = 0.16 < \omega_{uu} = \omega_{dd}$, and $k = -0.4 > \frac{f_u - \sqrt{f_u^2 + f_d^2}}{f_d}$. $H = 2.34 > 0$. Table 1 below shows the values of other variables.

Table 1	a_{iu}	a_{id}	V_{iu}	V_{id}	β
Co-op	30.93	12.37	0.15	0.03	25.98
Up-IOF	21.81	-	0.14	-	18.32
Down-IOF	-	21.81	-	0.14	18.32

The values in the second example, determining point B, are $\omega_{ud}=9>\omega_{uu}=\omega_{dd}$, and $k=-0.5<\frac{f_u-\sqrt{f_u^2+f_d^2}}{f_d}$. $H=3.04>0$. ($\sqrt{\omega_{ud}}>\frac{g_u}{\sqrt{2r}\left(1-k^2\right)}\left[\left(f_u-kf_d\right)-\sqrt{f_u^2+f_d^2}\right]-\sqrt{\omega_{uu}}$, so B is above the curve.) Table 2 below shows the values of other variables.

Table 2	a_{iu}	a_{id}	V_{iu}	V_{id}	β
Co-op	35	17.5	0.15	0.23	26.25
Up-IOF	24.67	-	0.22	-	18.5
Down-IOF	-	24.67	-	0.22	18.5

A is an efficient point for the cooperative, even though the chain interdependency is not so high. This is evidence of the cognition advantage of the cooperative. Without introducing the monitoring intensity principle, efficient point A would never be accessible. But a low enough ω_{ud} (indicating a high enough cognitive ability, due to innovation and information sharing for instance) can compensate such a high k, leading the cooperative to be efficient in the end.

B is another efficient point for the cooperative, even with a much lower cognitive ability. It justifies the interdependency advantages of the cooperative. In an environment that the processor of the cooperative knows so little, but the chain interdependency is high enough to cover, then the IOFs can still be dominated.

Here we would like to highlight the mechanism behind. Recall that the expected value of the total surplus is the sum of the principal's payoff and

CEO's payoff: $E(\pi + U) = y - c(a_{iu}, a_{id}) - \frac{1}{2} rVar(w) - M(V)$. In the first example, a higher k directly increases the costs of the activities and indirectly drops the activities, causing the total output y to decrease, but a much lower ω_{ud} reduces the monitoring costs and thus the risk aversions more compared to the IOFs, leading to an efficient cooperative. In Table 1, the sum of the cooperative activities is slightly less than the IOFs', but the sum of the variances is just the opposite, especially for the downstream variance. This justifies that the cognition effect matters more in this example, and by reducing the variances-related costs, the cooperative is performing better than the two IOFs.

The other example is just the other way around. When ω_{ud} increases, the monitoring costs and risk aversions rise, but a lower k will trigger higher activities and output to compensate more. In Table 2, the variances are kind of similar, but the sum of the cooperative activities is larger than the IOFs'. It verifies that the chain interdependency effect counts more in this case, and by motivating more activities, the cooperative can be efficient.