Organizational structure and the endogeneity of cost: Cooperatives, For-Profit Firms and the cost of procurement

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Abstract

In this paper, we show formally that cooperatives can possess an informational - and hence cost - advantage compared to For Profit Firms. This advantage is directly linked to the goal alignment between the cooperative and its members, and is influenced by the extent of income redistribution between members. Hence the standard practice of modeling the cooperative and the FPF as having identical cost structures appears to be theoretically unsound.

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1 Introduction

An important insight obtained from incentive theory is that privately held information is valuable to those that possess it, while it imposes a cost on those that do not. With access to full information about its agents' characteristics, for instance, a principal is able to entice the agents to exert the most efficient effort or production at a cost (net of the next best alternative) exactly equal to that incurred by the agents. If agents possess private information about their characteristic, however, a principal cannot perfectly price discriminate.[1] Instead, the principal must incur an additional cost in the form of an informational rent paid to all but the less efficient agent to elicit the appropriate effort. This additional cost arises because of the so-called agency problem - the goals of the principal do not align with those of the agents and the principal must incur a cost to bring these goals more into alignment.

The observation that goal alignment influences costs in principal-agent relationships suggests that, all else equal, the costs associated with eliciting the desired behavior from agents will be smaller when the goals of the principal and the agent are similar. Specifically, the greater is the rent that a principal attempts to extract from its agents, the greater will be the costs associated with procuring production; conversely, the less is the rent that the principal tries to extract, the less will be the procurement costs. As a consequence organizations that have greater goal alignment between the principal and the agents will have lower costs. To the extent that this lower cost allows organizations to better compete, organizational form and procurement costs are jointly endogenous.

A well-documented example of organizations with different alignments between the goals of the principal and the agents is found in the case of cooperatives and for-profit firms (FPFs). In a FPF, the goals of the principal (the firm) and its agents are typically in conflict - an increase in profit for the FPF generally means a loss of profit for the agents. Cooperatives,

[1] Even with perfect information, a principal may be unable to perfectly price discriminate because of institutional factors - e.g., a principal may be required legally to make a contract offered to one person available to everyone else that requests it. Faced with this situation, the principal has to use the contract terms to elicit information about an agent's characteristics and the discussion in the text is applicable.

however, have different goals - these have been expressed variously as service at cost and the maximization of aggregate member welfare (with or without consideration of membership size) - in both of these interpretations, the goals of the cooperative and its members are more closely aligned.[2] However, this goal alignment is unlikely to be perfect. As Banerjee et al. point out, cooperatives are likely to suffer from internal rent seeking, as particular members undertake activities to enlarge their share of the surplus generated by the co-op; in such cases, the goal pursued by the co-op is unlikely to be the one preferred by the membership at large. Cook (1995) discusses similar problems in agricultural cooperatives.

The purpose of this paper is to show formally that cooperatives can possess an informational - and hence cost - advantage compared to FPFs and that this advantage is directly linked to the goal alignment between the cooperative and its members. This informational advantage is influenced by the extent to which the cooperative has a goal of redistributing income among its members. When the goals of the members and their cooperative are perfectly aligned (i.e., when the co-op acts to maximize aggregate member welfare), the co-op is able to procure production at exactly the cost incurred by its members - the cooperative incurs no informational cost. And as expected, the greater is the degree to which the co-op redistributes income, the greater are the procurement costs that it faces.

A key implication of this result is that organizational structure and costs cannot be considered independently of each other. Since the costs that a firm must incur to procure a product are determined along with the degree of goal alignment that exists between the firm and its suppliers, the choice of organizational structure - to the extent that this influences goal alignment - affects the costs of the firm.

Recognizing that costs and organizational form are not independent means that the common practice of modeling different organizational forms as having identical cost structures is theoretically unsound. For instance, the behavior of co-ops and FPFs are often compared

[2]Bonin, Jones, and Putterman examine the objectives and behavior of producer cooperatives, while Sexton (1984) and LeVay (1983) provide an overview of the objectives of agricultural cooperatives. See Hansmann for a general treatment of the differences and similarities of FPFs and cooperatives.

through an examination of the impact of the different objective functions that these two firms are thought to possess. The maintained assumption in such analysis is that the cost structure of these firms is independent of the objective function. However, as this paper shows, when informational asymmetries are significant and the co-op undertakes little redistribution, the co-op should be modeled as having lower procurement costs.

Consideration of the informational costs of different organizational forms is important in developing a full understanding of the strengths and weaknesses of these forms. Co-operatives, for instance, are often thought to possess a number of cost disadvantages compared to IOFs because of the poorly defined property rights that the cooperative structure creates.[3] Yet, despite these cost disadvantages, producer cooperatives, for instance, appear to be at least as robust as FPFs once they come into existence (Bonin, Jones and Putterman). Similarly, Sexton and Iskow find no evidence that agricultural co-ops operate less (or more) efficiently than IOFs. The inclusion of informational costs into the analysis of these different organizational forms may shed some light on their relative performance.

In addition to developing new insights into the relationship between organizational structure and costs, the paper makes a contribution to the theoretical literature on incentives. A standard result in the incentive literature is that the most efficient agent will always be enticed to produce at the first best level. As this paper demonstrates, this conclusion hinges on the assumption that either the principal's objective is linear with respect to aggregate production or that the revenue generated from the output of individual agents can be aggregated in an additive way. When these conditions do not hold, as is reasonably the case for many market situations (e.g., when a firm's output influences price), it can be shown that the most efficient agent will overproduce compared to the first best level. The resulting production/effort pattern across agents in turn affects the distribution of informational rents among the agents.

[3] Bonin, Jones and Putterman provide an overview of these costs for producer cooperatives, while Cook and Vitaliano discuss these costs in the case of agricultural co-ops. See Hansmann for a general discussion.

The paper is structured as follows. The next section presents the general structure of the model. This section is followed by an examination of procurement decision of a FPF and then a cooperative. After a comparison of the pricing decisions by the FPF and the cooperative, and the resulting output and welfare levels, the paper concludes with some observations on how the analysis can be extended to capture other informational problems (e.g., moral hazard) and to examine oligopolistic market structures.

2 Model setup

The context for the problem examined in this paper is a group of producers (or agents) that sell their output/services to a processor, who in turns sells a processed product further downstream. The producers differ in their productivity of producing the output/service; while this productivity is privately held information, the processor does have knowledge of the underlying distribution of producer types. The producers are constrained to sell their output to the processor.[4]

Specifically, consider a continuum of agents of mass unity. Individual production q costs $c(q, \theta)$, where parameter θ belongs to the set $\Theta = [\underline{\theta}, \bar{\theta}]$ with $\underline{\theta} > 0$ and represents the producer's ability to transform inputs into production. For simplicity, it is assumed throughout the paper that $c(q, \theta) = \theta c(q) + k$ with $c' > 0$, $c'' > 0$, so that agents with a low type are more efficient in producing a given output and $k > 0$ is a fixed cost. The linearity assumption with respect to θ allows for the Spence-Mirrlees condition (that is $\partial^2 c/\partial\theta\partial q$ is of constant sign) to be naturally satisfied, but the analysis can be easily extended to more general cost functions under the Spence-Mirrlees assumption. Agents are distributed along the line segment according to ability density function $f(\theta)$ and cumulative function $F(\theta)$. It is assumed

[4]The set-up of the problem examined in this paper is similar to that in Vercammen, Fulton and Hyde who examine a group of farmers selling their product to a cooperative marketing organization. Guesnerie and Laffont, in their classic adverse selection paper, consider a self-managed firm that maximizes a welfare function defined over the output of the firm's workers. This paper departs from both papers in a couple of crucial ways - it considers the case where the revenue generated from the output of individual agents cannot be aggregated in an additive way and it explicitly compares the contracts offered by a cooperative and a FPF, thus allowing a comparison of these two organizational forms.

that $f(\theta) > 0$ for every θ. Moreover, the hazard ratio $\frac{F(\theta)}{f(\theta)}$ is assumed to be strictly increasing in θ (monotone hazard rate property).[5] Importantly, parameter θ is private information to the agent while the empirical distribution function $F(\theta)$ is common knowledge to agents and processors. Equivalently, the processor knows the type of each agent but institutional constraints prevents it from perfectly discriminating among agents according to their ability. Regardless of the reason, however, the processor must consider pricing schedules that ensures self-selection by the agents.

The revenue received by the processor from the downstream sale of the processed product depends on the total output produced by the agents. Specifically, the net revenue function $R(Q)$ is a function of total production $Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta)$ and contains all costs of processing the final good. The net revenue function is assumed to be strictly concave.

The analysis begins with an examination of the pricing decisions made by an FPF, first under conditions of perfect information and then under conditions of asymmetric information. The analysis then moves to an examination of the pricing decisions made by a cooperative that is assumed to provide the processing service at cost - i.e., all revenues net of the non-raw product costs are returned to the members. The cooperative case is applicable to both production cooperatives and agricultural marketing cooperatives. The cooperative is assumed to maximize an aggregate welfare function defined over the profits earned by its agent members.[6] The use of a welfare function is designed to capture situations where equity considerations among the members are important and/or where rent seeking by members results in the co-op favoring some members more than others. In addition to considering a general welfare function, the paper specifically examines two special cases - one where the co-op is utilitarian and maximizes aggregate member and another where the co-op pursues a Rawlsian objective

[5] This regularity condition is made in order to prevent the incidence of "pooling" in the optimal contract resulting from the probability function, that is a contract in which the same allocation is selected for different values of θ.

[6] Carson (1977) considers a cooperative that maximizes a welfare function defined over the utilities of the members. Zusman (1982) argues that the use of an objective function to capture the behavior of a co-op is subject to difficulties that arise because of the nature in which group decisions are typically made. The explicit modeling of group decision processes would greatly complicate the model and is left as an avenue for future research.

and maximizes the welfare of the least efficient member.

3 Contracting with an investor-owned-firm

Assume that producers can only sell their product to a processor that is a for-profit firm (FPF). Applying the revelation principle, the firm proposes to these agents a menu of contracts composed of a production level $q(\theta)$ and the associated transfer $t(\theta)$. The FPF wants to maximize its expected profit, that is its expected net revenue minus the expected transfer to be paid to agents.

3.1 Complete information situation as a benchmark case

Before analyzing the optimal procurement policy under incomplete information, consider the complete information situation where the FPF knows the agent's type. In this situation, the FPF has only to ensure participation of the agents whose outside opportunities are assumed to yield a constant profit normalized to zero. Hence, the FPF's problem can be written as follows:

$$\max_{q(.),t(.)} \int_{\underline{\theta}}^{\overline{\theta}} [R(Q) - t(\theta)]\, dF(\theta)$$

$$\text{s.t.} \quad \pi(\theta) = t(\theta) - \theta c(q(\theta)) - k \geq 0 \tag{IR}$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta) dF(\theta) \tag{1}$$

Since leaving rents in the hands of agents is costly for the FPF, it is easily seen that (IR) constraints are binding at the optimum ($\pi^{PI}(\theta) = 0$, $\forall\theta$, where PI stands for perfect information). Replacing $t(.)$ by its value in the objective function gives:

$$\max_{q(.)} \int_{\underline{\theta}}^{\overline{\theta}} [R(Q) - \theta c(q(\theta))]\, dF(\theta) - k$$

$$\text{s.t. } Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta) dF(\theta).$$

To solve this problem, it is useful to proceed in two steps. In the first step, the optimal production schedule $q(.)$ that minimizes the cost of procurement for a given total production level Q is found by considering the following problem:

$$\max_{q(.)} \int_{\underline{\theta}}^{\overline{\theta}} -\theta c(q(\theta))dF(\theta) - k$$
$$\text{s.t.} \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) = Q.$$

Denote ν as the Lagrange multiplier of the constraint. The Lagrangian is written as follows:

$$\mathcal{L} = \int_{\underline{\theta}}^{\overline{\theta}} -\theta c(q(\theta))dF(\theta) + \nu \left(\int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) - Q \right).$$

Maximizing over $q(.)$ gives:

$$\nu = \theta c'(q(\theta)) \tag{2}$$

Equation (2) gives a production schedule $q(\theta, \nu)$ which implicitly depends on ν, where ν can be interpreted as the shadow cost of total production Q. Note from this first order condition that the marginal costs of all agents, regardless of their θ-type, are equalized at the optimum. The shadow cost ν is linked to the fixed Q through the constraint:

$$\int_{\underline{\theta}}^{\overline{\theta}} q(\theta, \nu)dF(\theta) = Q \Rightarrow \nu \equiv \nu(Q). \tag{3}$$

It is easily seen that $\nu(Q)$ is increasing in Q. Indeed, differentiating (3) w.r.t. Q, gives:

$$\int_{\underline{\theta}}^{\overline{\theta}} \frac{\partial q(\theta, \nu)}{\partial \nu} \nu'(Q)dF(\theta) = 1 \tag{4}$$

which yields $\nu'(Q) = 1/ \left(\int_{\underline{\theta}}^{\overline{\theta}} \frac{\partial q(\theta,\nu)}{\partial \nu} dF(\theta) \right) > 0$ (differentiating (2) w.r.t. ν gives $\frac{\partial q(\theta,\nu)}{\partial \nu} = 1/ (\theta c''(q(\theta, \nu))) > 0$).

Hence, the minimum cost of procurement $C(Q)$ of a total quantity Q can be written as follows:

$$C(Q) = \int_{\underline{\theta}}^{\overline{\theta}} t(\theta)dF(\theta) = \int_{\underline{\theta}}^{\overline{\theta}} [\theta c(q(\theta, \nu(Q)) + k] \, dF(\theta)$$

which is strictly increasing and convex.[7]

[7] Indeed, we have $C'(Q) = \int_{\underline{\theta}}^{\overline{\theta}} \theta c'(q(\theta, \nu(Q)) \frac{\partial q(\theta,\nu)}{\partial \nu} \nu'(Q)dF(\theta) = \nu(Q) > 0$ (using (4) and (2)) and $C''(Q) = \nu'(Q) > 0$.

The second step of solving the FPF'S problem involves determining the optimal total quantity Q^{PI} by maximizing the revenue net of the procurement cost $(R(Q) - C(Q))$. The result of this maximization gives:

$$R'(Q^{PI}) = C'(Q^{PI}) = \nu(Q^{PI}).$$

Overall, the result is that the production level assigned to a type-θ agent is the first best level which equalizes the marginal net revenue with the marginal cost of production:

$$R'(Q^{PI}) = \theta c'(q^{PI}(\theta)) \tag{5}$$

with $Q^{PI} = \int_{\underline{\theta}}^{\overline{\theta}} q^{PI}(\theta)dF(\theta)$. For simplicity, we implicitly assume that the total surplus of production is positive, that is $\int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^{PI}) - \theta c(q^{PI}(\theta)) - k\right] dF(\theta) \geq 0$.

Note also that differentiating (5) with respect to θ yields to:

$$\dot{q}^{PI}(\theta) = -\frac{c'(q^{PI}(\theta))}{\theta c''(q^{PI}(\theta))} < 0$$

which confirms that $q^{PI}(\theta)$ decreases in θ.

3.2 Incomplete information

Under asymmetric information, the FPF's faces the following problem:

$$\max_{q(.),t(.)} \int_{\underline{\theta}}^{\overline{\theta}} [R(Q) - t(\theta)]\, dF(\theta)$$

$$\text{s.t.} \quad \pi(\theta) = t(\theta) - \theta c(q(\theta)) - k \geq 0 \tag{IR}$$

$$\pi(\theta) \geq t(\tilde{\theta}) - \theta c(q(\tilde{\theta})) - k \quad \forall \theta, \tilde{\theta} \tag{IC}$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) \tag{6}$$

As above, the analysis is carried out in two steps. In the first step the optimal procurement cost $C(Q)$ of a fixed quantity Q is determined. Let us denote η the Lagrange multiplier of the constraint (6) on total production, which once again can be interpreted as the shadow cost of Q. We then obtain the following lemma.

Lemma 1 *At the optimum, any θ-type agent produces a production level q such that*

$$\eta = \left[\theta + \frac{F(\theta)}{f(\theta)}\right] c'(q) \tag{7}$$

Proof: See Appendix A. ∎

Compared to the complete information case, the marginal cost $\theta c'(q)$ of individual production is now augmented by the extra marginal cost $(F/f)c'(q)$ due to incentive compatibility. Denote the total marginal cost $(\theta + F/f)c'(q)$ as the *virtual marginal cost* of θ-type agent. Equation (7) indicates that at the optimum there is equalization of all virtual marginal costs to the shadow cost η of total production Q. However, the presence of an added incentive cost does not imply here that individual production levels are everywhere downward distorted compared to the complete information case because the value of the multiplier η may differ from the one under complete information (ν). In addition, note that the assumption on the distribution function $F(.)$ ensures that the production level decreases monotonically in θ so that the neglected monotonicity constraints (13) are satisfied.[8]

Using Lemma 1, individual production can be written as a function of type and shadow price: $q = q(\theta, \eta)$. Hence, there is a connection between η and Q through constraint (6):

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta, \eta) dF(\theta) \Rightarrow \eta = \eta(Q). \tag{8}$$

This connection means that the production level assigned to the most efficient agent, which is given by $\eta(Q) = \underline{\theta} c'(q(\underline{\theta}))$, is distorted relative to the optimal production under complete information. The distortion arises because the optimal Q under incomplete information will differ from the optimal Q under complete information, as will be shown below.

With these results, the total procurement cost $C(Q)$ can be expressed as follows:

$$\begin{aligned} C(Q) &= \int_{\underline{\theta}}^{\overline{\theta}} t(\theta) dF(\theta) \\ &= \int_{\underline{\theta}}^{\overline{\theta}} \left\{ \left[\theta + \frac{F(\theta)}{f(\theta)}\right] c(q(\theta, \eta(Q))) \right\} dF(\theta) + k \end{aligned}$$

[8] From (7) and the convexity of $c(.)$, it is easily seen that the monotone hazard rate property is a sufficient condition for $q(.)$ to be strictly decreasing in θ.

with $C(Q)$ being strictly increasing and convex in Q.[9]

The second step in solving the FPF's problem consists of maximizing the (concave) objective function $R(Q) - C(Q)$ to obtain the optimal quantity Q^F under incomplete information (where F indicates the FPF) which is given by

$$Q^F = \int_{\underline{\theta}}^{\overline{\theta}} q^F(\theta) dF(\theta).$$

The main results on the comparison of the incomplete and complete information cases are stated in the following proposition.

Proposition 1 *Consider a privately-owned processor. Under incomplete information,*

(i) *the total production level Q^F is lower than the total production level Q^{PI} under complete information,*

(ii) *individual production levels $q^F(\theta)$ are upward or downward distorted depending on the agent's type and are given by*

$$R'(Q^F) = \left[\theta + \frac{F(\theta)}{f(\theta)}\right] c'(q^F(\theta)).$$

More precisely, there exists a unique interior threshold type $\tilde{\theta}$ which produces at his first best level ($q^F(\tilde{\theta}) = q^{PI}(\tilde{\theta})$). Any θ-type agent more efficient than this threshold type over-produces ($q^F(\theta) > q^{PI}(\theta)\ \forall \theta < \tilde{\theta}$) whereas any θ-type agent less efficient than this threshold type under-produces ($q^F(\theta) < q^{PI}(\theta)\ \forall \theta > \tilde{\theta}$).

(iii) *A strictly positive rent given by $\pi^F(\theta) = \int_\theta^{\overline{\theta}} c(q^F(u))du$ is left to any type of agent except the least efficient one ($\pi^F(\overline{\theta}) = 0$).*

Proof: See Appendix B. ■

Asymmetric information thus entails an upward shift in the procurement cost function compared to complete information. Indeed, as indicated in the proof, it is sufficient to notice

[9] The proof is similar to the one under complete information. Indeed, $C'(Q) = \int_{\underline{\theta}}^{\overline{\theta}} \left\{ \left[\theta + \frac{F(\theta)}{f(\theta)}\right] c'(q(\theta, \eta(Q))) \frac{\partial q(\theta, \eta(Q))}{\partial \eta} \eta'(Q) \right\} dF(\theta)$. Using (7) and differentiating (8) w.r.t. Q shows that $C'(Q) = \eta(Q)$ and hence $C''(Q) = \eta'(Q) > 0$.

that any incentive compatible and cost-minimizing production schedule $q(.)$ that results in total production Q would cost $k+\int_{\underline{\theta}}^{\overline{\theta}}\left\{\left[\theta+\frac{F(\theta)}{f(\theta)}\right]c(q(\theta)\right\}dF(\theta)$ under asymmetric information whereas the corresponding cost would be $k+\int_{\underline{\theta}}^{\overline{\theta}}\{\theta c(q(\theta)\}\,dF(\theta)$ under complete information. As a consequence, the optimal quantity Q^F under incomplete information is lower than its counterpart Q^{PI} under complete information.

More interestingly, while asymmetric information induces a lower production level from an aggregate point of view, it also results in a reallocation of production from inefficient agents to efficient agents. Figure **??** depicts the links between marginal costs and revenues at the individual (left hand side panel) and the aggregate level (right hand side panel). Compared to the perfect information outcome, the most efficient agents over-produce while the less efficient agents under-produce. Individual production under asymmetric information only coincides with the first-best level for an intermediate-type agent. Hence, we obtain a property that can be coined as "*efficiency somewhere in the middle*" rather than the "efficiency at the top" found in most adverse selection problems.

{INSERT Figure **??**}

The "efficiency somewhere in the middle" result comes from the non-linearity of the total revenue function $R(Q)$ and can be contrasted with the standard result from the adverse selection literature where it is usually assumed that the principal's objective is linear with respect to aggregate production or that the non-linear revenue of individual production can be aggregated in a additive way to form total revenue (see Maskin and Riley (1984) in the context of price discrimination by a monopolist or Mussa and Rosen (1978) in the context of discrimination through quality). In the context of this model, the imposition of linearity would amount to assuming that $R(Q)$ is linear in Q or that the total revenue can be written as $R=\int_{\underline{\theta}}^{\overline{\theta}}r(q(\theta))dF(\theta)$ where $r(q)$ is the revenue of individual production. With this formulation, the usual result of efficiency at the top and under-production elsewhere would be obtained.

4 Contracting with a cooperative

A processor organized as a cooperative has a different objective compared to the FPF but nevertheless faces the same informational constraints. Assume that the cooperative manager who designs the contracts has to take into account equity considerations. A simple way to introduce this notion is to consider that the manager's objective is to maximize an increasing, concave function $\mathcal{W}(.)$ of profit levels ($\pi(\theta)$) obtained by the agent members. The absolute degree of inequality aversion is thus given by $\sigma(.) = -\mathcal{W}''(.)/\mathcal{W}'(.)$. When $\sigma(.) = 0$, then the cooperative is not averse to inequality and the manager maximizes aggregate profit (or equivalently the average individual profit). In this utilitarian scenario, the goals of the members and the manager are in perfect alignment. When the cooperative is infinitely averse to inequality then the manager maximizes the lowest level of rent among members (i.e., the manager acts according to the Rawls maxi-min criterion). In all cases, however, the manager is constrained to exactly balance the budget - i.e., the net revenue from production must cover the total transfer to the members.

4.1 Complete information

As with the FPF, consider first the situation of perfect information. The manager's problem can be written as follows:

$$\max_{q(.),t(.)} \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta)$$

$$\text{s.t.} \quad \pi(\theta) = t(\theta) - \theta c(q(\theta)) - k \geq 0 \tag{IR}$$

$$\int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q) - t(\theta)\right] dF(\theta) = 0 \tag{BC}$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) \tag{9}$$

Intuitively, under complete information or equivalently perfect price discrimination, the cooperative processor should perform exactly as an FPF from the production point of view. This result is stated in the following proposition.

Proposition 2 *Under complete information, the cooperative processor offers contracts that induce perfect information individual production levels $q^{PI}(\theta)$ for all θ-type agents; the result is that total production Q^{PI}. is also at the perfect information level. Moreover, whenever the absolute degree of inequality aversion σ is strictly positive, the level of rent is constant for all agents and is equal to the average production surplus:*

$$\pi(\theta) = \pi^* = \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^{PI}) - \theta c(q^{PI}(\theta)) - k\right] dF(\theta) \geq 0, \; \forall \theta \in \Theta.$$

Proof: See Appendix C. ■

Proposition 2 indicates that the FPF and the cooperative are equally efficient from a production viewpoint, since in both situations the agents produce at the perfect information level. This result does not depend on the downstream market structure, i.e., whether the Coop or the FPF are price takers or price makers. The result also does not depend on the degree of inequality aversion in the cooperative. Thus, under complete information, there is no conflict between incentives and income redistribution issues inside the cooperative. However, while the two organizations are equally efficient, their distributional impacts are different. The FPF extracts all the surplus in the relationship, while the cooperative's manager transfers all the surplus to the agents.

In the special case where there is no aversion to inequality ($\sigma = 0$), the optimal rent level for any agent is undetermined. Indeed, any rent schedule that meets the budget constraint requirement, that is such that

$$\int_{\underline{\theta}}^{\overline{\theta}} \pi(\theta) dF(\theta) = \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^{PI}) - \theta c(q^{PI}(\theta)) - k\right] dF(\theta),$$

is optimal. This result is easily understood, since the cooperative's manager has no specific preferences with respect to the distribution of incomes as long as the budget constraint is met.

4.2 Incomplete information

Under asymmetric information, the problem to be solved can be written as follows:

$$\max_{q(.),t(.)} \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta) \text{ s.t. (IR), (IC), (BC) and (9)}$$

Eliminating the transfer $t(.)$, this program becomes:

$$\max_{q(.),\pi(.)} \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta)$$

$$\text{s.t.} \quad \text{(IR), (IC), (9) and}$$

$$\int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q) - \pi(\theta) - \theta c(q(\theta)) - k\right] dF(\theta) = 0 \tag{BC}$$

Solving this problem gives the following lemma that characterizes the optimal (separating) production schedule $q^C(.)$ and the rent schedule $\pi^C(.)$, where C stands for the Coop. Let us also denote $Q^C = \int_{\underline{\theta}}^{\overline{\theta}} q^C(\theta)dF(\theta)$ the total production level under incomplete information. Note that μ is the Lagrange multiplier of the budget constraint (BC).

Lemma 2 *The optimal production schedule $q^C(.)$ satisfies the following rule:*

$$R'(Q^C) = \left[\theta + \frac{\phi(\theta)}{f(\theta)}\right] c'(q^C(\theta))$$

where

$$\phi(\theta) = F(\theta) - \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u)}{\mu}.$$

Moreover, a positive rent given by $\pi^C(\theta) = \pi^C(\overline{\theta}) + \int_{\theta}^{\overline{\theta}} c(q^C(u))du$ is left to any type of agent.

Proof: See Appendix D. ■

The implication of lemma 2 is that at the optimum, the marginal revenue of total production should be equated at with the virtual marginal cost of individual production, where the latter is the sum of the true marginal cost ($\theta c'(q(\theta))$) and the extra marginal cost due to incentive compatibility ($\frac{\phi(\theta)}{f(\theta)}c'(q(\theta))$).

Finally, from incentive compatibility constraints (IC), recall that we have

$$\begin{aligned}\pi^C(\theta) &= t^C(\theta) - \theta c(q^C(\theta)) - k \\ &= \pi^C(\overline{\theta}) + \int_{\theta}^{\overline{\theta}} c(q^C(u))du.\end{aligned}$$

Exhibiting $t^C(\theta)$ and replacing in the budget constraint (BC) gives:

$$\begin{aligned}\pi^C(\overline{\theta}) &= \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^C) - \int_{\theta}^{\overline{\theta}} c(q^C(u))du - \theta c(q^C(\theta)) - k\right] dF(\theta) \\ &= \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^C) - \left(\theta + \frac{F(\theta)}{f(\theta)}\right) c(q^C(\theta)) - k\right] dF(\theta) \qquad (10)\end{aligned}$$

using integration by parts.

Therefore, we have two cases: Either the participation constraint at $\overline{\theta}$ is binding or it is not, that is $\pi^C(\overline{\theta}) = 0$ or $\pi^C(\overline{\theta}) > 0$. For simplicity, we will focus in the following on the case where $\pi^C(\overline{\theta}) > 0$ and hence it is given by (10). We will come back later to the case when the participation constraint is binding (see section 4.5). We obtain easily the following lemma which indicates that when $\pi^C(\overline{\theta}) > 0$, the Lagrange multiplier μ of the budget constraint is equal to the expected marginal utility of income at the optimum.[10]

Lemma 3 *If $\pi^C(\overline{\theta}) > 0$ at the optimum, then $\mu = \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}'(\pi^C(u))dF(u) > 0$.*

Proof: When $\pi^C(\overline{\theta}) > 0$, we get that $\lambda(\overline{\theta}) = 0$ and consequently from (25), we obtain the desired result.

Before turning to the general case, the following section is devoted to the analysis of special cases with regards to the welfare function. ■

4.2.1 The utilitarian and the Rawlsian managers

First, we note that when the cooperative has no aversion to inequality ($\mathcal{W}'(.) = 1$), then $\mu = 1$ and any type of agent produces at the first best level because $\phi(\theta) = 0$ for any θ. Hence, there is no conflict between redistribution of wealth inside the cooperative and incentives in

[10] Note that we would obtain the same result if the cooperative manager is not obliged to take into account the participation constraints of farmers when designing his production policy.

the absence of inequality aversion. This results does not remain true when the cooperative is strictly averse to inequality.

To complete the study, it is useful to look for the extreme situation of infinite aversion to inequality, that is the Rawlsian case. When the absolute degree of inequality aversion σ is infinite, the cooperative manager's objective is to maximize the profit of the least efficient agent, namely $\pi^C(\bar{\theta})$. By looking at the budget constraint (10), one can note that this objective is equivalent to

$$\max_{q(.)} \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q) - \left(\theta + \frac{F(\theta)}{f(\theta)} \right) c(q(\theta)) - k \right] dF(\theta)$$

subject to $Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta) dF(\theta)$, which is exactly the problem of the For-Profit-Firm under incomplete information. The solution is hence given by the production schedule $q^F(.)$ defined in Proposition 1 and the rent profile defined by

$$\pi(\theta) = \pi(\overline{\theta}) + \int_{\theta}^{\overline{\theta}} c(q^F(u))du$$

where $\pi(\overline{\theta}) = \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^F) - \left(\theta + \frac{F(\theta)}{f(\theta)} \right) c(q^F(\theta)) - k \right] dF(\theta)$. Hence, each agent receives first a base compensation $\pi(\overline{\theta})$ which is exactly the profit of the FPF and second an extra rent $\int_{\theta}^{\overline{\theta}} c(q^F(u))du$ in order to fulfill incentive compatibility constraints.

We thus obtain the striking result that a cooperative manager who is infinitely averse to inequality implements the same production profile as the FPF, but will nevertheless give back all the aggregate surplus of production through the base compensation $\pi(\overline{\theta})$ and the extra rent. Indeed, recall that the base compensation is zero for agents working for a FPF. The intuition of this result is as follows. Because of the budget constraint, the only way to maximize the least efficient agent's profit is actually to minimize the extra informational rents left to all more efficient types, which is exactly the task pursued by the FPF. Hence, it comes at no surprise that there is no essential difference between the Rawlsian cooperative and the FPF except that in the cooperative case the total surplus net of virtual costs is entirely redistributed to all agents through the base compensation $\pi(\overline{\theta})$.

4.2.2 Finite aversion to inequality

The following proposition states that aversion to inequality entails a downward or upward distortion on production levels depending on the type, except for two intermediates values in Θ where the first-best production level is obtained. In addition, we show that asymmetric information leads the inequality averse cooperative to reduce globally production. But for this to be possible, the total level of rents left to agents must be compatible with the budget constraint.

Proposition 3 *Assume that aversion to inequality is positive and finite ($0 < \sigma(.) < \infty$) and that the optimal level of individual production is monotonically decreasing in θ. If leaving a strictly positive rent to any type of agent is compatible with the budget constraint, then*

(i) *the total production level Q^C is lower than the total production level Q^{PI} under complete information,*

(ii) *individual production levels $q^C(\theta)$ are upward or downward distorted depending on the type of agents and are given by*

$$R'(Q^C) = \left[\theta + \frac{\phi(\theta)}{f(\theta)}\right] c'(q^C(\theta)).$$

More precisely, there exists two interior threshold types θ_1 and θ_2 with $\theta_1 < \theta_2$, which produce at their first best level ($q^C(\theta_i) = q^{PI}(\theta_i)$, $\forall i = 1, 2$). Any θ-type agent more efficient than θ_1 or less efficient than θ_2 over-produces ($q^C(\theta) > q^{PI}(\theta)$ $\forall \theta < \theta_1$ or $\theta > \theta_2$) whereas any θ-type agent less efficient than θ_1 but more efficient than θ_2 under-produces ($q^C(\theta) < q^{PI}(\theta)$ $\forall \theta_1 > \theta > \theta_2$).

Proof: see Appendix E. ■

Here again, asymmetric information entails an upward shift in the procurement cost function compared to complete information but only when the cooperative is averse to inequality. Consequently, the optimal quantity Q^C under incomplete information and aversion to inequality is lower than its counterpart Q^{PI} under complete information. We thus obtain a situation similar to the one when agents contract with a FPF but for a different reason. Moreover, the conflict between redistribution and incentives yields to reallocate production from intermediately efficient agents towards more efficient *and* less efficient agents. Indeed, the most efficient agents and the less efficient agents overproduce while the other ones underproduce. We thus obtain a property that can be coined as "*efficiency somewhere twice in the middle*" which comes once again from the non linearity of $R(.)$.[11]

{INSERT Figure 2}

This result can be explained as follows. It is important to remark that incentive compatibility requires to give an informational rent $\int_{\theta}^{\overline{\theta}} c(q^C(u))du$ to all agents except for the least efficient one (in addition to the base payment $\pi^C(\overline{\theta})$). Obviously this conflicts with the search of more equality among the members. Note also that distorting production downwards on some interval allows for a reduction in the informational rents left to all more efficient agents. Reducing informational rents will then contribute to more equality but at the expense of productive efficiency. This explains the downward distortion on production levels for intermediate types of producers. For the agents whose types are very inefficient (close to $\bar{\theta}$), the number of agents that would benefit from redistribution through a reduction in rents is very small. Hence, the efficiency consideration dominates and calls for almost undistorted production schedules. However, as virtual marginal costs are all equalized to the marginal revenue of total production $R'(Q^C)$ which is upward distorted relative to the complete information situation, the consequence is that the less efficient agents overproduce. Now, for the most efficient type $\underline{\theta}$, there is no lower types on which one can economized rents by distorting production. Hence, there is no distortion for the most efficient type which then call for overproduction for $\underline{\theta}$ and for its neighborhood by continuity of the production schedule.

[11] Note that under linearity of $R(.)$, we would have obtained first best levels of production for the upper and the lower bound of Θ and underproduction elsewhere.

4.3 Comparison with the FPF

The following proposition states an important result which indicates that the cooperative is always (weakly) more efficient than the FPF.

Proposition 4 *Assume that the optimal level of production is monotonically decreasing in θ. Whether the participation constraint of the least efficient agent is binding or not, the processor organized as a cooperative is always more efficient than the For-Profit Firm from the production viewpoint ($Q^{PI} \geq Q^{C} \geq Q^{F}$).*

Proof: The difference between the incentive distortion when the processor is an FPF and the one when the processor is a cooperative can be written as follows:

$$\frac{F(\theta)}{f(\theta)} - \frac{F(\theta)}{f(\theta)}\left[1 - \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^{C}(u))dF(u)}{\mu F(\theta)}\right] = \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^{C}(u))dF(u)}{\mu f(\theta)} > 0.$$

This indicates that the marginal individual virtual production cost is everywhere higher when the processor is a for-profit firm compared to the cooperative. Hence, it must be that the total quantity sold by a FPF is lower than the total quantity sold by a cooperative. ■

Note that this result does not depend on the particular value of μ and hence it holds whether the participation constraint is binding or not. Our analysis has shown that both FPF and the cooperative distort production schedules in case of asymmetric information but for different reasons. While the FPF faces the classic rent extraction-efficiency trade-off, the inequality-averse cooperative faces an equity-efficiency trade-off. However, the aggregate distortion due to inequality aversion is less important than the aggregate distortion implied by rent extraction.

Nevertheless, this does not mean that any type of agent would produce more when contracting with a cooperative than when contracting with a FPF. Indeed, for the most efficient agent ($\underline{\theta}$), it is easily seen that because the marginal cost is simply $\theta c'(q)$ in any case, then we have

$$q^{F}(\underline{\theta}) > q^{C}(\underline{\theta}) > q^{PI}(\underline{\theta})$$

and by continuity of production schedules, this remains true in a neighborhood of $\underline{\theta}$. As a conclusion, a FPF would offer the most efficient agents to produce more compared to a cooperative.

4.4 Monotonicity of production schedule

Finally we have to check whether the proposed production schedule are monotonically decreasing in θ in order to fulfill the second order conditions. Recall that individual production levels are given by

$$R'(Q^C) = \left[\theta + \frac{\phi(\theta)}{f(\theta)}\right] c'(q^C(\theta)) \tag{11}$$

where

$$\phi(\theta) = F(\theta) - \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u)}{\mu}.$$

Differentiating (11) with respect to θ, we obtain that:

$$\left[1 + \frac{d}{d\theta}\left(\frac{\phi(\theta)}{f(\theta)}\right)\right] c'(q^C(\theta)) + \left[\theta + \frac{\phi(\theta)}{f(\theta)}\right] c''(q^C(\theta))\dot{q}^C(\theta) = 0$$

Hence, a necessary and sufficient condition for $q^C(.)$ being decreasing is

$$1 + \frac{d}{d\theta}\left(\frac{\phi(\theta)}{f(\theta)}\right) > 0.$$

Rewriting this condition, we have

$$1 + \frac{d}{d\theta}\left(\frac{F(\theta)\varphi(\theta)}{f(\theta)}\right) = 1 + \varphi(\theta)\frac{d}{d\theta}\left(\frac{F(\theta)}{f(\theta)}\right) + \frac{F(\theta)}{f(\theta)}\varphi'(\theta) > 0$$

where $\varphi(\theta) = 1 - \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u)}{\mu F(\theta)} > 0$ and

$$\varphi'(\theta) = \frac{f(\theta)}{\mu\left[F(\theta)\right]^2}\left[\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u) - \mathcal{W}'(\pi^C(\theta))F(\theta)\right] \leq 0$$

because $\mathcal{W}'(\pi^C(.))$ is increasing in θ. This indicates that when $\varphi'(\theta)$ is very negative which happens when $\mathcal{W}$ is sufficiently concave, it might happen that the necessary and sufficient condition of monotonicity of production schedule is not fulfilled.[12] Consequently, bunching

[12] Note that when there is no inequality aversion ($\mathcal{W}'(.) = 0$) then $\varphi'(\theta) = 0$ and consequently the monotonicity condition is fulfilled. By continuity, this remains true for low levels of inequality aversion.

a subset of types of agents is the optimal strategy for the manager because it is the only way to fulfill incentive compatibility constraints. All the types that are bunched together are offered a uniform contract say $(\bar{q}, \bar{t})$. Unfortunately, it appears that analyzing the emergence of bunching is very difficult for this level of generality. In particular, we may have several bunching sets over the interval Θ. But, if we assume further that $F(.)$ is the uniform distribution then it is possible to show the following result.

Proposition 5 *When $F(.)$ is uniform over $\Theta = \left[\underline{\theta}, \overline{\theta}\right]$, the bunching set whenever it appears is a set $\left[\hat{\theta}, \bar{\theta}\right]$ which comprises the less efficient agents.*

Proof: Recall that the necessary and sufficient condition for the production profile to be decreasing is

$$h(\theta) = 1 + \frac{d}{d\theta}\left(\frac{\phi(\theta)}{f(\theta)}\right) > 0.$$

Using $f(\theta) = \frac{1}{\overline{\theta}-\underline{\theta}}$, we obtain that

$$h(\theta) = 2 - \frac{\mathcal{W}'(\pi^C(\theta))}{\mu}$$

and differentiating h, we get

$$h'(\theta) = -\frac{\mathcal{W}''(\pi^C(\theta))\dot{\pi}^C(\theta)}{\mu} < 0$$

because the marginal value of profit is increasing in θ. This indicates that actually the incentive distortion $\frac{\phi(\theta)}{f(\theta)}$ is concave and hence that $h(.)$ can only be negative on a subset $\left[\hat{\theta}, \bar{\theta}\right]$. ■

4.5 When the participation constraint is binding

Here, we have $\pi^C(\overline{\theta}) = 0$ which implies that $\lambda(\overline{\theta}) = \mu - \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}'(\pi^C(u))dF(u) > 0$. Consequently, we still have $\mu > 0$ and

$$\pi^C(\theta) = \int_{\theta}^{\overline{\theta}} c(q^C(u))du.$$

Hence, the budget constraint (10) reduces to

$$\int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^C) - \left(\theta + \frac{F(\theta)}{f(\theta)} \right) c(q^C(\theta)) - k \right] dF(\theta) = 0.$$

Moreover, we still have

$$R'(Q^C) = \left[\theta + \frac{\phi(\theta)}{f(\theta)} \right] c'(q^C(\theta)).$$

Proposition 6 *Assume that the optimal level of production is monotonically decreasing in θ. When the participation constraint is binding at $\overline{\theta}$, then*

(i) *the total production level Q^C is lower than the total production level Q^{PI} under complete information,*

(ii) *individual production levels $q^C(\theta)$ are upward or downward distorted depending on the type of agents and are given by*

$$R'(Q^C) = \left[\theta + \frac{\phi(\theta)}{f(\theta)} \right] c'(q^C(\theta)) \qquad \text{with } Q^C = \int_{\underline{\theta}}^{\overline{\theta}} q^C(\theta) dF(\theta).$$

More precisely, there exists an upward distortion for the most efficient agent who over-produces compared to the first best.

Proof: Part (i): identical to part (i) in proposition 3.

Part (ii): From part (i), $R'(Q^C) > R'(Q^{PI})$. Then, when $\theta = \underline{\theta}$, individual virtual marginal costs are identical ($\theta c'(q)$) because $\phi(\underline{\theta}) = 0$. This implies that $q^C(\underline{\theta}) > q^{PI}(\underline{\theta})$. Hence, by continuity of the monotonically decreasing production schedule, it must be true that the curve $q^C(\theta)$ intersects at least once the curve $q^{PI}(\theta)$. ■

Hence, there is no essential difference with the preceding case, except that the base payment is now constrained to zero due to the budget constraint. Note that in the special case of no inequality aversion, we obtain that $\lambda(\overline{\theta}) = \mu - 1 > 0$. Hence, we have

$$R'(Q^C) = \left[\theta + \frac{F(\theta)}{f(\theta)} \frac{\mu - 1}{\mu} \right] c'(q^C(\theta)).$$

This indicates that when the participation constraint is binding, then even if there is no inequality aversion, the cooperative has to distort production schedules. This contrasts with the preceding case where leaving a strictly positive rent to any type of agent was compatible with the budget constraint.

5 Conclusion

Incentive theory suggests that goal alignment between a principal and its agents affects the costs that the principal must incur when contracting with these agents. The purpose of this paper was to formally investigate the linkage between goal alignment and costs using a FPF and a cooperative as examples of organizational structures that embody different degrees of goal alignment. The main result of the paper is that cooperatives can possess an informational - and hence cost advantage - relative to FPFs, an advantage that stems directly from the greater goal alignment that exists in these organizations.

As expected, the cooperative's cost advantage is the greatest when its goals and those of the members are in perfect alignment. Such an outcome occurs when the cooperative manager is given the utilitarian objective of maximizing aggregate member profits. If the manager is required to redistribute income among the members to maximize some non-utilitarian welfare function, then the co-op's cost advantage diminishes. In the extreme case where the manager acts in a Rawlsian fashion to maximize the profits of the least well-off member, the cost advantage completely disappears and the output profile of the co-op matches that of the FPF. Otherwise, the cooperative is more efficient than the FPF because the equity-efficiency trade-off calls for less productive distortion than the rent extraction-efficiency trade-off faced by the FPF.

The co-op and FPF are also equivalent from the production point of view in one other setting - when both firms have complete information about their agents/members type. This production similarity, of course, does not carry over to the surplus obtained by the producers, since the FPF extracts all the surplus created, while the co-op completely transfers this surplus to its members.

In addition to providing some insights into the importance of goal alignment on the costs of an organization, the paper also shows that the manner in which the output of the agents enters the principal's objective function can have important results for the nature of the contract between the principal and the agent. Specifically, when the assumption that either the principal's objective is linear with respect to aggregate production or that the revenue generated from the output of individual agents can be aggregated in an additive way is relaxed, the standard result that the most efficient agent always operates at the first-best level no longer holds. More specifically, it is found that there is "efficiency somewhere in the middle" rather than the usual "efficiency at the top."

An important implication of the results of this paper is that the cost structure of an organization cannot be separated from the goals and objectives of the organization. At the most basic level, this observation means that comparative analysis of different organizational forms has to take account of the impact that goal alignment will have on the costs incurred by the organization. Cooperatives and public firms are often compared to FPFs using the implicit or explicit assumption that costs are similar and that the only difference in the organizations is the objective that they pursue. As this paper shows, however, the nature of the organization's objective can influence the costs incurred by the organization. Further work is required to determine the magnitude of this cost difference in different situations and to better understand the conditions that make these informational issues important.

The conclusion that organizational structure affects costs suggests an interdependency that could have consequences for market structure and performance. Specifically, to the extent that organizations like co-ops have lower costs, then they should have some advantages when competing against FPFs in the market. A topic for future research is to examine the implications of informational cost advantages for cooperatives when they compete actively with FPFs, either in the upstream market over the output of the agents/members or in the final market downstream. As well, since co-ops are often believed to suffer cost disadvantages because of the lack of well defined property rights that result from the organizational form, it is necessary to examine the interaction of these advantages and disadvantages, particularly as they affect the co-op's ability to compete with their FPF counterparts.

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Appendix

A Proof of Lemma 1

The production schedule that allows total quantity Q to be produced at least cost can be obtained by solving the following problem:

$$\max_{q(.),t(.)} \int_{\underline{\theta}}^{\overline{\theta}} -t(\theta)dF(\theta)$$

$$\text{s.t.} \quad \pi(\theta) = t(\theta) - \theta c(q(\theta)) - k \geq 0 \tag{IR}$$

$$\pi(\theta) \geq t(\tilde{\theta}) - \theta c(q(\tilde{\theta})) - k \quad \forall \theta, \tilde{\theta} \tag{IC}$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta)$$

Usual arguments (see Guesnerie and Laffont (1984)) show that (IC) constraints can be reduced to:

$$\dot{\pi}(\theta) = -c(q(\theta)) < 0 \tag{12}$$

$$\dot{q}(\theta) \leq 0. \tag{13}$$

Equation (12) indicates that (IR) reduces to $\pi(\overline{\theta}) \geq 0$ because the rate of growth of rents is negative. Replacing $t(.)$ by its value given by (IR) and ignoring the monotonicity constraint (13) (it will be checked later), results in the following problem:

$$\max_{q(.),\pi(.)} - \int_{\underline{\theta}}^{\overline{\theta}} \{\pi(\theta) + \theta c(q(\theta)) + k\} \, dF(\theta)$$

$$\text{s.t.} \quad \pi(\overline{\theta}) \geq 0$$

$$\dot{\pi}(\theta) = -c(q(\theta))$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta)$$

Since it is clear that the individual rationality constraint binds at the optimum ($\pi(\overline{\theta}) = 0$), integrating (12) gives:

$$\pi(\theta) = \int_{\theta}^{\overline{\theta}} c(q(u))du. \tag{14}$$

Replacing the above expression in the objective function and integrating by parts gives the following problem:

$$\max_{q(.)} - \int_{\underline{\theta}}^{\overline{\theta}} \left\{ \left[\theta + \frac{F(\theta)}{f(\theta)} \right] c(q(\theta)) \right\} dF(\theta) - k$$
$$\text{s.t.} \quad Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta) dF(\theta).$$

Denote η the Lagrange multiplier of the constraint in this problem. The Lagrangian can then be written:

$$\mathcal{L} = - \int_{\underline{\theta}}^{\overline{\theta}} \left\{ \left[\theta + \frac{F(\theta)}{f(\theta)} \right] c(q(\theta)) \right\} dF(\theta) + \eta \left(\int_{\underline{\theta}}^{\overline{\theta}} q(\theta) dF(\theta) - Q \right)$$

and maximizing over $q(.)$ gives:

$$\eta = \left[\theta + \frac{F(\theta)}{f(\theta)} \right] c'(q(\theta))$$

B Proof of Proposition 1

Part (i): the proof is by contradiction. Suppose that $Q^F \geq Q^{PI}$ or equivalently that $\eta(Q^F) \leq \nu(Q^{PI})$. Then because $\theta + \frac{F(\theta)}{f(\theta)} \geq \theta$, it would be the case that $q^F(\theta) \leq q^{PI}(\theta)$ $\forall \theta \in \Theta$. But this leads to $Q^F < Q^{PI}$ which contradicts the assumption. Hence, $Q^F < Q^{PI}$ necessarily.

Part (ii): From part (i), $\eta(Q^F) > \nu(Q^{PI})$. Then, when $\theta = \underline{\theta}$, individual virtual marginal costs are identical ($\theta c'(q)$) which implies that $q^F(\underline{\theta}) > q^{PI}(\underline{\theta})$. This remains true by continuity in a neighborhood of $\underline{\theta}$. Now, when $\theta = \overline{\theta}$, assume that $\eta(Q^F) \geq \left(\overline{\theta} + \frac{1}{f(\overline{\theta})} \right) c'(q^{PI}(\overline{\theta}))$. Then, it must be true that $q^F(\overline{\theta}) > q^{PI}(\overline{\theta})$. This results in over-production everywhere and hence to $Q^F > Q^{PI}$, which is impossible. Hence, it is necessarily the case that $q^F(\overline{\theta}) < q^{PI}(\overline{\theta})$, which by continuity of the monotonically decreasing production schedule yields a unique interior type $\tilde{\theta}$ such that $q^F(\tilde{\theta}) = q^{PI}(\tilde{\theta})$. Finally, $\tilde{\theta}$ is given by $q^F(\tilde{\theta}) = q^{PI}(\tilde{\theta})$ which implies from (2) and (7) that

$$\frac{\eta(Q^F)}{\tilde{\theta} + \frac{F(\tilde{\theta})}{f(\tilde{\theta})}} = \frac{\nu(Q^{PI})}{\tilde{\theta}}.$$

Part (iii): this comes from previous result (see (14)).

C Proof of Proposition 2

Once gain, we proceed in two steps. First, having eliminated the transfer t by replacing it by $\pi + \theta c(q) + k$, we look for the optimal production schedule $q(.)$ and optimal utility schedule $\pi(.)$ that maximizes the objective of the cooperative for a given total production level Q:

$$\max_{q(.),t(.)} \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta)$$

$$\text{s.t.} \quad \pi(\theta) \geq 0 \tag{IR}$$

$$\int_{\underline{\theta}}^{\overline{\theta}} [R(Q) - \pi(\theta) - \theta c(q(\theta)) - k] \, dF(\theta) = 0 \tag{BC}$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) \tag{15}$$

Denote μ the multiplier of the budget constraint (BC) and ν the multiplier of constraint (15). Omitting the (IR) constraints for the moment, the Lagrangian writes as follows:

$$\mathcal{L} = \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta) + \mu \left(\int_{\underline{\theta}}^{\overline{\theta}} [R(Q) - \pi(\theta) - \theta c(q(\theta)) - k] \, dF(\theta) \right) + \nu \left(\int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) - Q \right)$$

Maximizing over the utility $\pi(\theta)$ yields to:

$$\left[\mathcal{W}'(\pi(\theta)) - \mu\right] f(\theta) = 0$$

which implies that the optimal level of utility is constant, which we denote π^* and hence we get $\mu = \mathcal{W}'(\pi^*)$. Now maximizing over $q()$ yields to:

$$\theta c'(q(\theta)) = \delta \tag{16}$$

where $\delta = \frac{\nu}{\mu}$. Notice that the marginal price of individual production is now weighted by the shadow cost of the budget constraint. This equation implicitly gives us a production schedule $q(\theta, \delta)$. Now, the link between δ and Q is established through constraint (15):

$$\int_{\underline{\theta}}^{\overline{\theta}} q(\theta, \delta)dF(\theta) = Q \Rightarrow \delta \equiv \delta(Q). \tag{17}$$

Finally, from the budget constraint, we obtain that π^*, which depends on Q, corresponds to the average surplus of production:

$$\pi^*(Q) = \int_{\underline{\theta}}^{\overline{\theta}} [R(Q) - \theta c(q(\theta, \delta(Q))) - k] \, dF(\theta).$$

It remains to maximize the objective of the cooperative with respect to total production Q:

$$\max_{Q} \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi^*(Q))dF(\theta) = \mathcal{W}(\pi^*(Q))$$

which yields to the following first-order condition,

$$\pi^{*\prime}(Q) = 0$$

that is,

$$\begin{aligned} R'(Q) &= \int_{\underline{\theta}}^{\overline{\theta}} \left[\theta c'(q(\theta, \delta(Q)))\frac{\partial q}{\partial \delta}\delta'(Q)\right] dF(\theta) \\ &= \delta(Q) \\ &= \theta c'(q(\theta)) \ \ \forall \theta. \end{aligned}$$

by using (16) and differentiating (17) w.r.t. Q. This indicates that at the optimum, agents produce at the individual first-best level given by $R'(Q^{PI}) = \theta c'(q^{PI}(\theta))$ where $Q^{PI} = \int_{\underline{\theta}}^{\overline{\theta}} q^{PI}(\theta)dF(\theta)$. They also receive the lump sum transfer $\pi^* = \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q^{PI}) - \theta q^{PI}(\theta) - k\right] dF(\theta) \geq 0$ which satisfies the neglected individual rationality constraints.

D Proof of lemma 2

Recall first that usual arguments show that (IC) can be replaced by:

$$\begin{aligned} \dot{\pi}(\theta) &= -c(q(\theta)) < 0 \\ \dot{q}(\theta) &\leq 0, \end{aligned}$$

which indicates that individual rationality constraints reduce to $\pi(\overline{\theta}) \geq 0$. In addition, neglect for the moment the monotonicity constraints $\dot{q}(\theta) \leq 0$ (it will be checked later). Then, eliminating the transfer t in the budget constraint gives:

$$\max_{q(.),\pi(.)} \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta)$$

$$\text{s.t.} \quad \pi(\overline{\theta}) \geq 0 \tag{IR}$$

$$\dot{\pi}(\theta) = -c(q(\theta)) \tag{18}$$

$$\int_{\underline{\theta}}^{\overline{\theta}} [\pi(\theta) + \theta c(q(\theta)) + k]\, dF(\theta) = R(Q) \tag{BC}$$

$$Q = \int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) \tag{19}$$

The Lagrangian corresponding to this problem is:

$$\begin{aligned} \mathcal{L} \;=\; & \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{W}(\pi(\theta))dF(\theta) + \int_{\underline{\theta}}^{\overline{\theta}} \lambda(\theta)\left[-c(q(\theta)) - \dot{\pi}(\theta)\right] d\theta \\ & +\mu \int_{\underline{\theta}}^{\overline{\theta}} \left[R(Q) - \pi(\theta) - \theta c(q(\theta)) - k\right] dF(\theta) + \nu \left(\int_{\underline{\theta}}^{\overline{\theta}} q(\theta)dF(\theta) - Q \right) \end{aligned} \tag{20}$$

where $\lambda(\theta)$ is the co-state variable associated with π, μ is the multiplier associated with the budget constraint and ν is the multiplier associated with (19).

Integrate by parts the term containing $\dot{\pi}(\theta)$:

$$\begin{aligned} \int_{\underline{\theta}}^{\overline{\theta}} \lambda(\theta)\dot{\pi}(\theta)d\theta &= \left[\lambda(\theta)\pi(\theta)\right]_{\underline{\theta}}^{\overline{\theta}} - \int_{\underline{\theta}}^{\overline{\theta}} \dot{\lambda}(\theta)\pi(\theta)d\theta \\ &= \lambda(\overline{\theta})\pi(\overline{\theta}) - \int_{\underline{\theta}}^{\overline{\theta}} \dot{\lambda}(\theta)\pi(\theta)d\theta \end{aligned}$$

since $\lambda(\underline{\theta}) = 0$ ($\pi(\underline{\theta})$ is free). Substituting this expression in the Lagrangian (20) gives:

$$\mathcal{L} = \int_{\underline{\theta}}^{\overline{\theta}} \mathcal{H}d\theta - \lambda(\overline{\theta})\pi(\overline{\theta})$$

where

$$\begin{aligned} \mathcal{H} \;=\; & \mathcal{W}(\pi(\theta))f(\theta) - \lambda(\theta)c(q(\theta)) + \dot{\lambda}(\theta)\pi(\theta) \\ & +\mu\left[R(Q) - \pi(\theta) - \theta c(q(\theta)) - k\right] f(\theta) + \nu\left(q(\theta)f(\theta) - Q\right) \end{aligned}$$

The necessary conditions for an optimum are as follows:

$$\frac{\partial \mathcal{H}}{\partial q} = -\lambda(\theta)c'(q(\theta)) - \mu\theta c'(q(\theta))f(\theta) + \nu f(\theta) = 0 \quad (21)$$

$$\frac{\partial \mathcal{H}}{\partial \pi} = \mathcal{W}'(\pi(\theta))f(\theta) + \dot{\lambda}(\theta) - \mu = 0 \quad (22)$$

$$\frac{\partial \mathcal{L}}{\partial Q} = \mu R'(Q) - \nu = 0 \quad (23)$$

$$\frac{\partial \mathcal{L}}{\partial \pi(\overline{\theta})} = -\lambda(\overline{\theta}) \leq 0 \text{ with } \lambda(\overline{\theta})\pi(\overline{\theta}) = 0,\ \pi(\overline{\theta}) \geq 0 \text{ (slackness condition).} \quad (24)$$

From (22), the optimal value of the co-state variable $\lambda(\theta)$ can be obtained by integration:

$$\lambda(\theta) = \mu F(\theta) - \int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi(u))dF(u) \quad (25)$$

recalling that $\lambda(\underline{\theta}) = 0$ since $\pi(\underline{\theta})$ is free.

Rearranging (21) gives:

$$\psi = \frac{\nu}{\mu} = \left[\theta + \frac{\lambda(\theta)}{\mu f(\theta)}\right] c'(q(\theta))$$

and from (23):

$$R'(Q) = \psi = \frac{\nu}{\mu},$$

This last expression indicates that the marginal revenue of total production should be equated with the marginal value ν of individual production weighted by the shadow cost μ of the budget constraint. Overall, using (25), the optimal production schedule $q^C(.)$ (where C stands for the Coop) satisfies the following rule:

$$R'(Q^C) = \left[\theta + \frac{\phi(\theta)}{f(\theta)}\right] c'(q^C(\theta))$$

where

$$\phi(\theta) = \frac{\lambda(\theta)}{\mu} = F(\theta) - \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u)}{\mu}.$$

E Proof of Proposition 3

Part (i): A preliminary result is needed to prove this. Let us first show that $\phi(\theta) = F(\theta) - \frac{\int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u)}{\mu} \geq 0$ that is $\delta(\theta) \equiv \mu F(\theta) - \int_{\underline{\theta}}^{\theta} \mathcal{W}'(\pi^C(u))dF(u) \geq 0$. Indeed, $\delta(\underline{\theta}) = \delta(\overline{\theta}) = 0$.

Moreover, $\delta'(\theta) = \left[\mu - \mathcal{W}'(\pi^C(\theta))\right] f(\theta)$. Note that $\mathcal{W}'(\pi^C(\theta))$ is strictly positive and also increasing in θ because $\mathcal{W}(.)$ is concave and $\pi^C(.)$ decreasing. Hence, we have three possible cases. First notice that $\mathcal{W}'(\pi^C(\overline{\theta}))$ cannot be lower than μ since otherwise $\delta(\theta)$ would be strictly increasing everywhere which is impossible. Second, $\mathcal{W}'(\pi^C(\underline{\theta}))$ cannot be higher than μ, otherwise $\delta(\theta)$ would be strictly decreasing everywhere which is also impossible. As a consequence, $\mathcal{W}'(\pi^C(\theta))$ necessarily intersects once the horizontal line μ and $\delta(\theta)$ is first increasing then decreasing. Overall, $\delta(\theta)$ is positive and consequently $\phi(\theta) \geq 0$.

Then the proof of part (i) is by contradiction. Suppose that $Q^C \geq Q^{PI}$ or equivalently that $R'(Q^C) \leq R'(Q^{PI})$. Then because $\theta + \frac{\phi(\theta)}{f(\theta)} \geq \theta$, it would be the case that $q^C(\theta) \leq q^{PI}(\theta)$ $\forall \theta \in \Theta$. But this would lead to $Q^C < Q^{PI}$ which contradicts the assumption. Hence, $Q^C < Q^{PI}$ necessarily.

Part (ii): From part (i), $R'(Q^C) > R'(Q^{PI})$. Then, when $\theta = \underline{\theta}$ or $\theta = \overline{\theta}$, individual virtual marginal costs are identical ($\theta c'(q)$) because $\phi(\underline{\theta}) = \phi(\overline{\theta}) = 0$. This implies that $q^C(\underline{\theta}) > q^{PI}(\underline{\theta})$ and $q^C(\overline{\theta}) > q^{PI}(\overline{\theta})$. Hence, by continuity of the monotonically decreasing production schedule, it must be true that the curve $q^C(\theta)$ intersects twice the curve $q^{PI}(\theta)$.

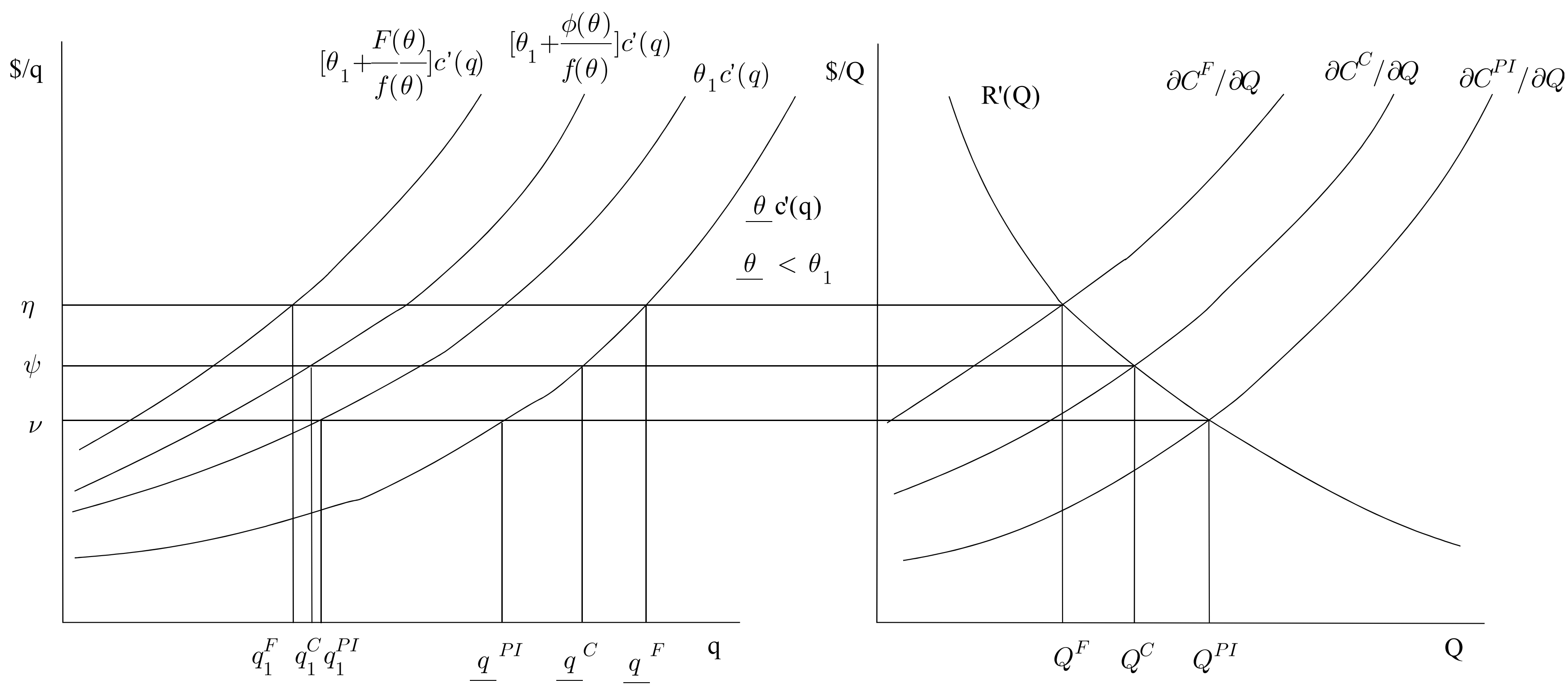
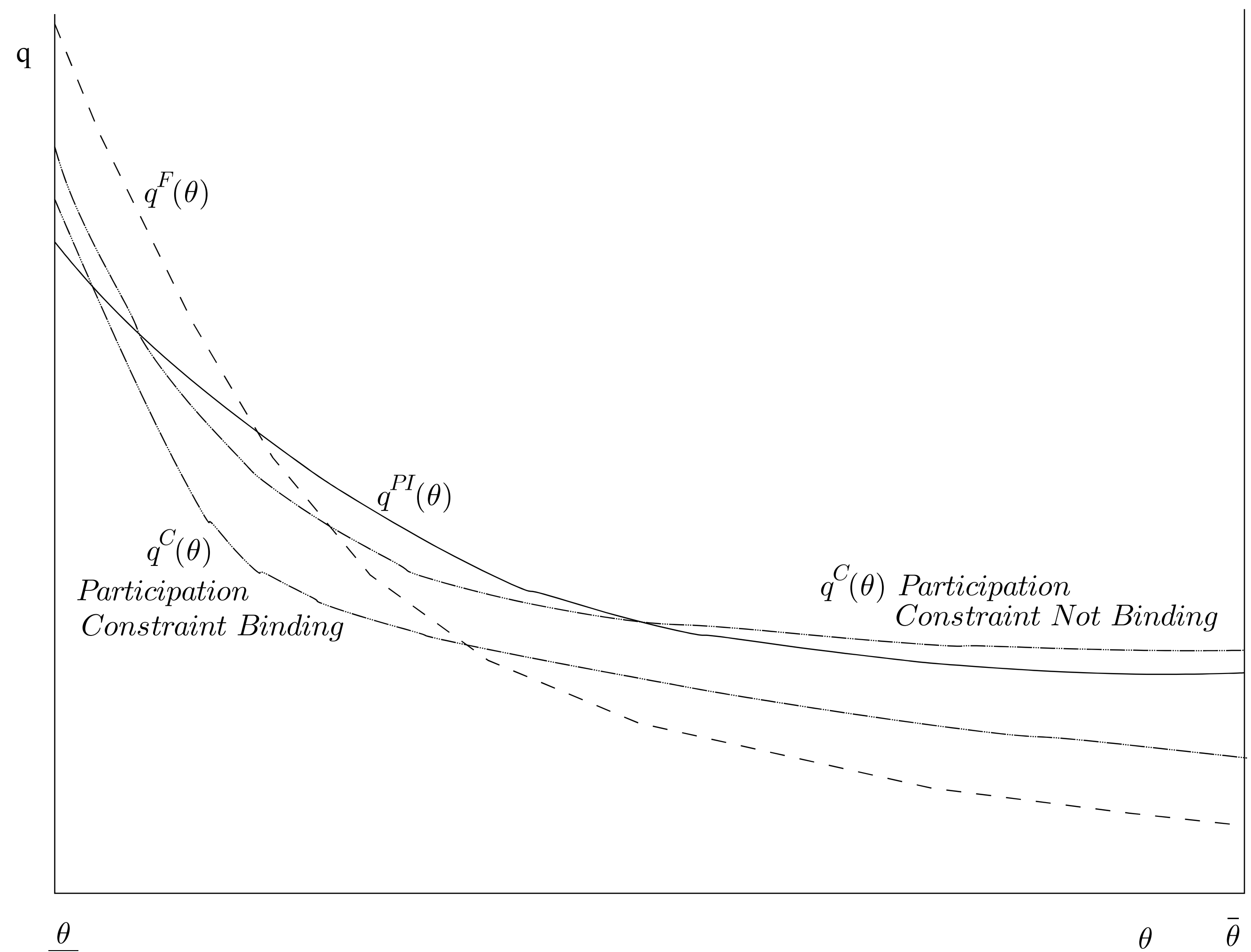


Figure 1 Individual and Aggregate Marginal Cost Functions: Perfect Information, For-Profit and Co-op Cases


q
q^F(θ)
q^PI(θ)
q^C(θ)
Participation
Constraint Binding
q^C(θ) Participation
Constraint Not Binding
θ
θ
θ̄