Financing and Access in Cooperatives*

Patrick Rey† and Jean Tirole‡

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Abstract

Cooperative undertakings account for a substantial share of developed market economies and that share is likely to grow with the advent of the new economy. The paper develops a dynamic investment framework in order to relate access policies, financing and growth of cooperatives. It shows how discriminating among users affects the viability of cooperatives and impacts social efficiency. It then argues that in most circumstances, the cooperative form, even when viable on a stand-alone basis, is a weak competitor against alternative organizational forms. Last, the paper stresses that access policies involve a standard social tradeoff between static efficiency and innovation.

Keywords: Cooperatives, Open Access, Discrimination, Investment.

JEL numbers: D7, L2, L3.

1 Introduction

Cooperative undertakings account for a substantial share of developed market economies. As was well documented by Hansmann (1996), even in the United States cooperatives dominate or at least figure prominently in a number of industries, such as agriculture,[1] credit cards, hardware, moving companies, electricity and the financial sector. Related forms of cooperative undertakings include joint ventures (R&D joint ventures, Intelsat, airline seat reservation systems, ...), consortia (undersea fiber optic cable systems), and partnerships (law firms, investment banks,...).

Cooperatives may become even more prominent with the advent of the new economy. For example, an important question confronting firms and antitrust authorities is whether standards and B2B exchanges should be controlled by a single user, or by a community of users,

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†IDEI and GREMAQ (CNRS UMR 5604), Toulouse.

‡IDEI and GREMAQ (CNRS UMR 5604), Toulouse, CERAS (CNRS URA 2036), Paris, and MIT.

[1] For example, cooperatives market 32% of the products produced and processed in the agri-food chain.

whose extent then has to be defined. Another case in point is patent pools. Such pools have played a crucial role in the aerospace and automobile industries.[2] Patent pools still have not yet had the impact on the new economy[3] that might be expected from the observation that software, semiconductor and biotechnology products potentially infringe on thousands of intellectual property rights, so that pooling would ceteris paribus appear very desirable. Industry participants' concerns about how the pool will evolve and antitrust authorities' fear of improper use of pools to collude or erect barriers to entry may account for this currently low diffusion of pools.

The existence of cooperative undertakings can usually be traced to two forms of returns to scale in the provision of an input and to the concomitant eagerness of the users to protect themselves from monopoly behavior. First, returns to scale may be associated with large fixed costs. As Hansmann (1996, 1999) argues, the capital intensity of equipment manufacturing is often and incorrectly thought of as an important barrier to the emergence of cooperatives. For example, some of the largest farm supply cooperatives in the US run very capital-intensive operations (oil refining, seeds, fertilizers, ...); credit card cooperatives involve substantial sunk investment in telecommunications networks, software and branding. Because they are shared among the users, fixed costs in cooperatives give rise to "cost-sharing network externalities". The second form of returns to scale relates to "classical network externalities". Such network externalities arise for example for credit cards, moving companies, flower delivery services or alliances around a standard.

The governance of cooperatives raises many fascinating issues. This paper focuses on their financing: How do cooperatives manage their financing and growth? Do they have the proper investment incentives? When are they viable? Cooperatives rely primarily on the proportional

[2] See Merges (1996) for a discussion of these pools, as well as those related to collective rights organizations (such as the American Society of Composers, Authors and Publishers). Shapiro (2000) discusses pools in the context of semiconductors and standard setting.

[3] When pooling occurs it often takes the more limited form of cross licensing. Well-known patent pools in the new economy include the MPEG LA pool (protocol for compressing and transmitting digitalized audio and video signals) and the former Cylink-RSA public key encryption pool that for a while defined a de facto proprietary standard.

assessments levied on their members' usage of the facilities (the "unit retains" that are kept after patronage dividends are redistributed to the members) and equity investments by the members. They by and large have little or no access to external finance.[4]

The viability of cooperatives and their investment incentives are closely related to the cooperatives' access policies. Some cooperatives essentially do not discriminate between incumbents and new or expanding members. Most however practice such discrimination in various ways. Usage fees may decrease with past cumulative usage,[5] or may depend on the user's status (e.g., internal vs external in a patent pool). Cooperatives may ask for entry fees[6] or may allow older members to redeem their shares when they depart.[7] And many of the "new generation" farm cooperatives recently created in the US issue transferable and appreciable equity shares, which enable incumbents to recoup some of their investment when departing the venture

[4]External finance raises several issues in the case of a cooperative. Debt finance makes the cooperative highly sensitive to "runs" by members. In the absence of buffer, the desertion by some members increases the assessment levied on remaining members, who then themselves have a strong incentive to leave. Outside equity finance does not create such snowballing. But it (or more generally outside finance) raises control issues. Either outside equityholders have control over the firm and then the latter is run basically as an investor-owned corporation. Or control is granted to the users, in which case outside finance is marred by the "empty-shell syndrome". In the same way the creditors of a corporation are concerned that shareholders might distribute themselves excessive dividends and empty the firm of its value, outside financiers of a cooperative are preoccupied with the possibility that the profit potential be syphoned off by the members before they can recoup their initial investment. The scope for diversion, though, is different. Dividends received by shareholders are highly visible, so that debtholders can and typically do impose covenants restricting dividend distribution. In contrast, members of a cooperative can distribute themselves less verifiable "dividends" in the form of goldplated versions of the input supplied by the cooperative.

There are literal exceptions to this characterization. In the US tax-exempt nonprofit hospitals have been able (until the 1986 Tax Reform Act) to borrow to help cover substantial capital investments. But such cooperatives had access to collateral (relatively safe income streams, building, brandname) and, as we said, benefited from borrowing subsidies. The fact that many of these hospitals had trouble raising funds to cover their investment needs and converted to for-profit status in the 90's confirms the low access of cooperatives to external financing.

[5]See, e.g. Hansmann (1996) and Rathbone-Wissman (1993). For example, under a per-unit capital returns system, new members or members who increase their consumption must make new investments to reach a target capital-patronage ratio. Redemption programs include first-in, first-out redemptions, base capital methods (redeeming overinvested patrons), and percent-of-all-equities programs (redemptions proportional to outstanding equities).

[6]For example, the Microelectronics and Computer Technology Corporation (MCC), a large-scale IT project involving 21 participants had an entry fee of $150,000 at the onset (1983). Newcomers paid a $1,000,000 entry fee in 1986.

[7]Although, as noted by Hansmann (1999), redemptions are not as widespread as one might have expected. Rathbone and Wissman (1993), in their study of the various forms of redemption in agricultural coooperatives, document "special equity redemption programs," that redeem equity to existing members (in agriculture, exit from a cooperative is probably less subject to opportunistic behavior than in other industries). Common programs include payments to a member's estate after her death, age-of-patron / retirement programs, and disability programms. As one would expect, there are fewer retirement-from-farming or move-away programs.

(Cook-Iliopoulos 1999).

Access policies matter for both business and antitrust reasons. Liberal access policies allow new members to free-ride on previous investments; as we will see, such policies may prevent the venture from getting off the ground and they further encourage short-termism in investment decisions (an issue known as the "horizon problem" in the policy literature). At the other end of the spectrum, very restrictive access policies raise two concerns. First, they may excessively tax newcomers and make the venture underinclusive. Second, when the members compete on the product market, access policies may be used as a barrier to entry. Access policies therefore must strike the right balance between the protection of investment and openness.

To the best of our knowledge, there has been no analytical treatment of the issues covered in this paper. The recent theoretical literature on cooperatives[8] focuses on corporate governance and conflict issues and is not cast in a dynamic investment framework. In the paper we will point at some links between our work and two apparently distinct fields: the political economy of social security reform and public utility regulation.

The paper develops a simple overlapping-generations framework in order to capture the intergenerational conflicts between incumbents and new members. Investments are financed from assessments or from equity contributions levied from current members. Our study proceeds in a gradual manner in order to cleanly identify the relevant trade-offs. First, it focuses on the intergenerational conflicts by ignoring downstream competition. That is, the members of the cooperative interact only through their membership. In this framework we ask three questions: When are cooperatives viable and how is their investment affected by the absence of discrimination (section 2)? Are cooperative robust to competition from other cooperatives, discriminatory or non-discriminatory, and from for-profit companies, and how do cooperatives emerge in an environment in which alternative institutional forms are available (section 3)?Are cooperatives over or underinclusive and should the level of discrimination between old users and new users vary over time (section 4)? The analysis is then generalized to allow membership value to be eroded by the entry of new members and the paper studies the anticompetitive

[8]E.g., Glaeser-Shleifer (1998), Kremer (1998), Hart-Moore (1988) and Rey-Tirole (2001).

concerns associated with alternative access policies (section 5). Last, section 6 concludes.

2 Are cooperatives viable?

2.1 Model

To model the arrival of new agents/potential users and study access policies, we consider an overlapping generations framework.[9] Time is discrete, and the horizon infinite, $t = 0, 1, 2, \cdots$. Agents live for two consecutive periods. Each period, a generation with a large number, namely a continuum of mass 1, of agents is born, and an equal-size generation exits. The discount factor is denoted by $\delta < 1$.

At each date $t - 1$, an investment, costing I if incurred, is available, that brings about a technology for date t. This technology generates gross surplus θ for any agent who has access at t to the technology. This surplus can be thought of as the user's surplus increment relative to publicly available technologies at date t. The technology is a public good in that its ex post marginal cost is zero[10] and furthermore the individual gross surplus θ is independent of the number of agents who have access to the technology at t. Our formulation also implies that agents do not compete on the product market; otherwise, the individual surplus would depend on the access policy. As discussed in the introduction, we want to separate intergenerational conflicts from competitive issues and therefore delay the introduction of product market competition. Agents are risk neutral and do not face credit constraints. We will further assume that the investment is socially beneficial.

This section assumes that all agents have the same gross surplus θ from having access to the technology. [Section 4 will consider the case of within-generation heterogeneity and will

[9] The OLG model is a standard, Samuelsonian one. It is easy to generalize our results using, say, a Blanchard (1985) framework, in which agents' retirement follows a Poisson process. Similarly, the extension to time-dependent populations (n_0 , $n_1, ..., n_t ...$) is completely straightforward. It predicts a slower transition to the steady state (if the sequence n_t is increasing) than depicted here. It can also be used to study the mirror image of our model, that of a declining membership (the insights are then very similar to those presented here).

[10] Throughout the analysis, we focus on investment costs and ignore variable operating costs. In practice, the access charge a_t should be interpreted as the amount that needs to be added to variable costs in order to recover the fixed costs of investment.

look at inclusiveness.] The condition that the investment is socially beneficial is then:

$$2\delta\theta > I. \tag{1}$$

We will analyze the following institutions:

Investor owned corporation (IOC). The investor owned corporation is externally financed. Provided it has invested at date $t-1$, the IOC rents/licenses its technology at access charge a_t at date t.

Nondiscriminatory cooperative (NDC). The nondiscriminatory cooperative is the purest form of cooperative: There is no entry fee, no redemption rights and all users of the cooperative at a given date t pay the same amount a_t for the right to use the input produced by the cooperative. We assume that control rights over the investment decision in a cooperative (discriminatory or not) are allocated to the young members – otherwise investment would never take place.

Fully discriminatory cooperative (FDC). In a discriminatory cooperative, new members do not pay the same amount as established members. A fully discriminatory cooperative completely disconnects the assessments paid by the established members and by the newcomers. Without loss of generality (see below), we will formalize discrimination as the existence of an entry fee E_t to be paid by new members at date t and chosen by established members. The newcomers' entry fee is used to defray the investment cost I. By convention, new members otherwise pay the same usage price a_t as established members. [In this interpretation, the old-timers do not receive any equity redemption payment when they leave. They benefit from the newcomers' entry fee through the reduction in the access charge.]

In this section, we will assume that the firm's technology is proprietary, or more generally that there is no threat of entry by a rival firm (section 3 studies upstream competition).

2.2 Viability

We investigate the viability of the various organizational forms.

- *Investor-owned corporation.* Provided it has invested at $t-1$, the IOC sets access charge at date t so as to capture user surplus:

$$a_t = a^m = \theta,$$

and so its intertemporal profit is

$$V^m = \frac{2\delta\theta - I}{1-\delta}. \tag{2}$$

Investment is viable in an IOC, which captures the entire social surplus under user homogeneity.

• *Nondiscriminatory cooperative.* An NDC that gets off the ground has no trouble to keep going since the new members free ride on the old members' investment. To be certain, these new members know that their successors will in turn free ride on their own investments, but this cost is discounted. More formally, in steady state, assessments $a_t = a^{NDC}$ satisfy

$$2a^{NDC} = I,$$

so that the net surplus of a date-t new member ($t > 0$) is equal to

$$U_t^{NDC} = U^{NDC} = (1+\delta)\left(\theta - \frac{I}{2}\right),$$

and is positive under condition (1).

On the other hand, NDCs do not easily get started. To see why, consider the date-0 generation. It bears the brunt of the date-0 investment[11] and gets to use the technology only at date 1: $a_0 = I$, $a_1 = I/2$; generation 0's utility, if it invests, is therefore[12]

$$U_0^{NDC} = \delta\left(\theta - \frac{I}{2}\right) - I.$$

And so if

$$\theta < \left(\frac{1}{2} + \frac{1}{\delta}\right) I, \tag{3}$$

[11] Date-0 members may either contribute through lump-sum grants or entry fees, or else commit to an exclusive use of the cooperative at date 0 and pay a surcharge for the use of the (public) technology.

[12] Note the importance of the assumption that the NDC cannot exclude. At each instant old members would like to stop investment. They could do so by excluding new entrants or, if the membership were actually declining, by keeping control over the board. More generally, investment in an NDC will take place only if a controlling majority has a forward looking perspective.

the NDC never gets started.

• *Fully discriminatory cooperative.* Let us first consider the steady state of an FDC. Let $V^{FDC} = \theta - a^{FDC}$ denote the old members' equilibrium instantaneous payoff. In any period, the access charge is linked to the entry fee E by $2a = I - E$. The old generation optimally chooses the largest fee that the young generation is willing to pay:

$$E = \theta - a + \delta V^{FDC}.$$

Hence, in equilibrium[13]

$$E = E^{FDC} = \frac{1+\delta}{1-\delta}(2\theta - I),$$

and so

$$V^{FDC} = \frac{2\theta - I}{1-\delta}.$$

The first generation (born at date 0) thus extracts the entire surplus and gets

$$U_0^{FDC} = -I + \delta V^{FDC} = \frac{2\delta\theta - I}{1-\delta} = V^m,$$

while the later generations receive no surplus ($U_t^{FDC} = 0$ for $t > 0$). There is thus no difference between an IOC and an FDC when users are homogenous.

Proposition 2.1 *With homogenous users, an investor-owned corporation and a fully discriminatory cooperative are equivalent and efficient. The nondiscriminatory cooperative is steady state viable and efficient, but it does not get off the ground if condition (3) holds.*

A few remarks are in order. First, the equivalence between investor-owned corporations and fully-discriminatory cooperatives is quite general and extends for example to variable usage levels. In effect, the first generation in a fully discriminatory cooperative owns the facilities

[13] The steady-state access charge is equal to $a^{FDC} = [I - (1+\delta)\theta] / (1-\delta)$ and is thus negative. It should however be interpreted as a reduction in the usage fee charged for the input supplied by the cooperative, which is normalized to zero in our framework. In addition, if the demand for the input is variable, non-linear (e.g., two-part) tariffs should be used and the subsidy should be applied to the fixed part of the tariff in order to avoid distortions.

and is able to impose monopoly conditions on the new members. This exercise of monopoly power creates no welfare loss here because new members are homogenous and thus all "get on board".

Second, we have assumed that discrimination takes the form of an entry fee levied on the young generation and that this entry fee is used to defray the investment cost. In practice, discrimination may take several other forms. First, the cooperative may levy *seniority-based assessments*. That is, it may levy different access charges $\{a_t^o, a_t^y\}$ on the old and the young. Second, the association may pay a *redemption or dividend* d_t based on capital accounts (that is here to the old members). Third, the members may be endowed with a *transferable property right*. The exiting members then receive a (market determined) lump sum payment p_t when they leave the cooperative, which again amounts to reduce their effective usage fee. These various instruments are formally equivalent in our simple framework: setting a higher charge for young members ($a_t^y > a_t^o$) amounts to charging an entry fee $E_t = a_t^o - a_t^y$, whereas a transferable property right p_t reduces the effective fee charged to old members ($a_t^o = a_t - p_t$) and a redemption d_t both reduces the usage fee of the old members ($a_t^o = a_t - d_t$) and increases that of the young members ($a_t^y = a_t + d_t$). We thus have:[14]

Observation: A fully discriminatory cooperative can implement its optimal policy by using any of the following instruments: (i) entry fees; (ii) seniority-based assessments; (iii) redemptions or dividends; (iv) transferable property rights.

[14]In broader frameworks, these various instruments would no longer be redundant. For example, an entry fee (paid once for all) and a redemption policy (paid in several periods) have different impacts on young members' incentive to stay in the cooperative in the early stage of their membership. These two instruments also have differentiated impacts on credit constrained members.

There are also two minor caveats to the equivalence demonstrated in the text. The first is that access charges must be nonnegative; this may be a concern when entry fees are used to reduce the assessment and variable operating costs are not very high (in the above analysis of the FDC, where operating costs are zero, in steady state the access charge equals $a^* = (I - (1 + \delta)\,\theta) / (1 - \delta)$ and is indeed negative). Dividends or membership rights avoid this problem as they allow assessments to remain positive. Conversely assessments should not be so high as to discourage the user. The variety of instruments however allows the cooperative to implement its discrimination policy without striking these two rocks.

2.3 Robustness and extensions

• *Network externalities.* The analysis above accounts only for cost-sharing network externalities. It is easily generalized to also allow for more conventional network externalities. For example suppose that a member's gross surplus in a given period t is given by

$$\theta + v(n_t),$$

where n_t is the number of date-t users of the good, and v is an increasing function. The analysis goes through by replacing the per-member investment cost I/n_t by the "modified per-member investment cost"

$$\mathcal{I}(n) \equiv \frac{I}{n} - v(n).$$

In particular, a for-profit owner or the founders of a fully discriminatory cooperative appropriate the future flows of network externalities.

• *The horizon problem.* We have focused on the possibility that a socially desirable investment may not be incurred. The same ideas apply to choices among investments. Consider an inferior investment technology that costs only $J < I$ but yields surplus $\gamma < \theta$ to the following period's users, such that

$$2\delta(\theta - \gamma) > I - J.$$

The investor-owned corporation and the fully discriminatory cooperative fully internalize future benefits and so choose the superior technology in each period. In contrast, the founders of a nondiscriminatory cooperative, who bear the full cost of investment and receive only half of the benefits choose the inferior technology if

$$I - J > \delta(\theta - \gamma).$$

While this short-termist behavior is only transitory here – the cooperative reverts to the superior technology once it gets going –, it would arise repeatedly if the cooperative were to grow slowly over time.

3 Competition among organizational forms

3.1 Genesis of cooperatives

Section 2 focused on the viability of alternative organizational forms. Let us now look into the choice of organizational form. The analysis of section 2 points at two handicaps faced by the nondiscriminatory cooperative form in its competition with alternative institutions. First, it may not be viable. Second, even if it is viable, it is not in general in the interest of the founders to create a nondiscriminatory cooperative: adopting instead a discriminatory charter would allow them to capture some of the future generations' rents. These two reasons probably explain why most cooperatives actually discriminate.

There are however limits to discrimination. One such limit may come from antitrust enforcement of open access (see section 5). Another, more along the lines of section 2, is that a commitment not to discriminate may be necessary to reassure prospective or expanding members. To illustrate this argument in the case of prospective members, suppose that generation t must incur some fixed investment cost c at date $t-1$ in order to be able to derive gross surplus from access at t and $t+1$. Because this gross surplus is then expropriated through the entry fee (or other discriminatory instruments), the prospective members do not incur the fixed cost c, and the fully discriminatory cooperative is therefore unable to attract new members. In contrast, *a nondiscrimination charter, or more generally a charter that limits the feasible discrimination is a credible commitment not to expropriate the specific investments made by the future members.* Similarly, limiting some forms of discrimination such as equity redemption (which favors exiting members to the detriment of expanding ones) is a credible commitment not to expropriate the investments of current members.

In our view, such considerations play an important role in the genesis of cooperatives.[15] They may also explain why private property may voluntarily be turned into the public domain. For example, the Visa and MasterCard associations were originally investor-owned.[16] Turning the systems into (basically) nondiscriminatory cooperatives enabled the corporation to offer a credible commitment to other issuers and thereby to benefit from increased network externalities. A similar credibility argument often underlies the release of proprietary software to form a coalition around a standard or to initiate an open source process.

3.2 Contestability of upstream segment

Our natural monopoly model has assumed that the firm, regardless of its charter, is not threatened by entry. Let us in contrast assume that the investment technology is widely available, and so a new institution may emerge, that threatens the established upstream monopoly. We will assume that, when confronted with two alternative offers, the young generation coordinates to jointly take the offer that is best for its users (this is the "Pareto dominance" selection criterion often used in network economics).

• *Nondiscriminatory cooperative*. First, we note that an NDC, once it gets going, is immune to entry by a rival NDC. For, the incumbent NDC offers a nice deal to the young generation, whose representative member obtains $U^{NDC} = (1+\delta)\left(\theta - \frac{I}{2}\right)$. In contrast, even if it succeeded in attracting all members of this generation and the next, an entering NDC could offer at most $U_0^{NDC} = -I + \delta\left(\theta - \frac{I}{2}\right) < U^{NDC}$.

Interestingly, the incumbent NDC is not necessarily immune to entry by an FDC (or for that matter by an IOC). The intuition is that while offering a lower initial surplus, the FDC can promise the new generation of users the rents associated with the collection of entry fees

[15] Of course, other external elements may help cooperatives to get off the ground. For example, nonprofit hospitals in the US have benefitted from charitable contributions. Favorable tax treatment (especially before the Tax Reform Act of 1986) has also contributed to the development of cooperatives. Large R&D consortia often receive seed money or subsidies from governments. For example, European Community Esprit and Eureka IT funding programs in the 1980s contributed respectively to 50% and 35% of the costs of inter-firm R&D projects.

[16] Visa finds its origins in Bank of America's proprietary system, and MasterCard in the merger of proprietary systems owned by Wells Fargo Bank and Marine Midland Bank.

in the future: an FDC can thus successfully defeat an incumbent NDC whenever

$$U_0^{FDC} = V^m = \frac{2\delta\theta - I}{1-\delta} > U^{NDC} = (1+\delta)\left(\theta - \frac{I}{2}\right),$$

that is, when[17]

$$\frac{2\delta\theta - I}{2\theta - I} > \frac{1-\delta^2}{2}. \tag{4}$$

This fragility of NDCs to entry by FDCs may remind the reader of the political economy of pensions. Pay-as-you-go systems and FDCs are less favorable to the young (as opposed to the old) than NDCs and fully-funded-social-security systems. As is well-known it is quite difficult to move from a pay-as-you-go system to a fully-funded system while the reverse is obviously easier.

• *Fully discriminatory cooperative.* Let us now look at an FDC facing the threat of entry by another FDC (it can be shown that an NDC entrant cannot defeat an FDC incumbent). The past investment of the incumbent FDC confers an advantage which ensures its stability. However, the threat of entry reduces the amount that can be extracted from the new generations. To fix ideas, suppose that (1) the existing FDC decides whether to invest and sets an entry fee, and (2) young users choose whether to join the existing FDC or to form a new one. By creating a second venture, the young generation can secure itself at least $-I + \delta\theta$ even if the two ventures compete à la Bertrand for the new generation in the following period. Thus, if $I < \delta\theta$, the threat of entry forces the incumbent FDC to lower its entry fee (otherwise, entry is "blockaded" and the analysis in section 2.2 prevails).[18]

[17] When this condition is satisfied, some protection (e.g., in the form of exit fees) is required to ensure the sustainability of the NDC.

[18] The competitive pressure from the threat of entry is even larger if the existing venture cannot precommit itself to invest. Then, the young generation may be able to secure itself up to $-I + \delta V^{FDC}$; in this case, the existing venture cannot charge more than

$$E = I + \theta,$$

and all generations, including the first one, obtain the same surplus

$$-I + 2\delta\theta.$$

The following proposition summarizes this discussion:[19]

Proposition 1 *An incumbent nondiscriminatory cooperative is defeated by an entering investor-owned corporation or fully discriminatory cooperative if and only if condition* (4) *holds. In contrast, an incumbent fully discriminatory cooperative (or investor-owned corporation) is not defeated by a (discriminatory or nondiscriminatory) cooperative entrant; the threat of entry by another fully discriminatory cooperative may however limit the incumbent members' market power and force them to share their rents with the new generations.*

4 Heterogeneous users and inclusiveness

4.1 Dynamics of membership

Allowing users to enjoy different benefits is interesting for two reasons. First, heterogeneity introduces a distinction between viability and efficiency: an organizational form may support investment, but be underinclusive and therefore inefficient; in contrast, with homogenous users, viability always implied efficiency. Second, heterogeneity slightly differentiates the investor-owned corporation and the discriminatory cooperative.

Let us assume that, in a given generation, the agents' gross surpluses are distributed according to cumulative distribution $F(\theta)$ on $[0, \infty)$. We assume that the distribution is log concave: $\frac{f(\theta)}{1-F(\theta)}$ increases with θ.

• *Investor-owned corporation.* Let

$$\theta^m = \arg\max \{\theta[1 - F(\theta)]\}$$

denote the "monopoly cut-off", that is the type of the marginal user of the technology when

[19] This discussion does not explain the successful creation of agriculture cooperatives in response to the high prices charged by for-profit suppliers. Such events can however be rationalized if the for-profit faces some uncertainty with regard to its customers' characteristics (e.g., it may be uncertain about the customers' ability to undertake a collective action).

the technology is marketed by an IOC.[20] The monopoly profit is

$$V^m = \frac{2\delta\theta^m \left[1 - F\left(\theta^m\right)\right] - I}{1-\delta} \equiv \frac{\delta\pi^m - I}{1-\delta}.$$

We assume that an IOC is viable:

$$\delta\pi^m > I. \tag{5}$$

• *Nondiscriminatory cooperative.* In the *steady state* of an NDC, the marginal user's type θ^{NDC} is equal to the steady state access price a^{NDC}. And so θ^{NDC} is given by (the smallest root of):

$$2\theta^{NDC}\left[1 - F(\theta^{NDC})\right] = I.$$

The IOC is underinclusive relative to the NDC, since

$$\theta^{NDC} < \theta^m.$$

While the steady state outcome under an NDC is socially superior to the IOC outcome, there may be serious transition problems like in the case of homogenous users. The first generation bears the initial cost of investment but does not immediately benefit from the joint venture. So the NDC may never get off the ground. It can get going at date 0 only if there exists a sequence of marginal customers $\theta_0, \theta_1, \cdots, \theta_t, \cdots$, and uniform access charges $a_0, a_1, \cdots, a_t, \cdots$, such that

$$a_0[1 - F(\theta_0)] = I,$$

$$a_t[1 - F(\theta_{t-1}) + 1 - F(\theta_t)] = I \text{ for all } t \geq 1,$$

and

[20] We assume that the IOC cannot discriminate among the users according to their age. Otherwise, the IOC would offer nomember access at a low price, targeted to old users who have not joined in the previous period. From standard intertemporal (Coasian) price discrimination theory, we know that this would discourage some users (those with type only slightly above θ^m) from subscribing when they are young, which would lower the profitability of the IOC: *A policy of no discrimination between short- and long-term users allows the IOC to commit to monopoly access charges.* We will make the similar assumption for the NDC and the FDC.

Note in particular that this assumption undertates the extent of freeriding in cooperatives as it eliminates "footdragging" (the strategy adopted by some potential members of waiting until investment has been sunk to adhere to the cooperative).

$$\delta\theta_0 = a_0 + \delta a_1,$$

$$(1+\delta)\theta_t = a_t + \delta a_{t+1} \text{ for all } t \geq 1.$$

The interpretation is as follows. If at date 0, agents with type $\theta \geq \theta_0$ "contribute" (pay a_0), they get nothing in period 0 but the venture gets started, and so they will be able to benefit from the investment in period 1, provided they pay the access price a_1. And so on.

We will say that a sequence $\Theta = (\theta_0, \theta_1, \cdots)$ is *self-financing* if for all $t \geq 1$

$$(1+\delta)\theta_t \geq \left[\frac{1}{1-F(\theta_{t-1})+1-F(\theta_t)} + \frac{\delta}{1-F(\theta_t)+1-F(\theta_{t+1})}\right] I,$$

and

$$\delta\theta_0 \geq \left[\frac{1}{1-F(\theta_0)} + \frac{\delta}{1-F(\theta_0)+1-F(\theta_1)}\right].$$

That is, if at date t type θ_t is willing to join the venture provided all types above θ_t also join, and at dates $t-1$ and $t+1$ types above θ_{t-1} and θ_{t+1}, respectively, have joined and will join the venture. If it is nonempty, the set of types θ_t satisfying this condition for given θ_{t-1} and θ_{t+1}, has a lowest element, and this lowest element is nondecreasing in θ_{t-1} and θ_{t+1}. In words, potential users are willing to become members at date t if the venture is already bigger (θ_{t-1} smaller), since a wide membership spreads the fixed cost over a larger number of members ($a_t = I/[1-F(\theta_{t-1})+1-F(\theta_t)]$) and if it is expected that more users will join later on (θ_{t+1} smaller), since it reduces the anticipated level of assessments for the next period. The Appendix shows that if sequences $\Theta = (\theta_0, \theta_1, \cdots)$ and $\Theta' = (\theta'_0, \theta'_1, \cdots)$ are self-financing, so is $\Theta \bigwedge \Theta' = (\min(\theta_0, \theta'_0), \min(\theta_1, \theta'_1), \cdots)$:

Lemma 4.1 *If a self-financing sequence exists, then there exists a smallest self-financing sequence, $\hat{\Theta} = \left(\hat{\theta}_0, \hat{\theta}_1, ...\right)$ which thus Pareto-dominates (from the point of view of all generations) all other self-financing sequences. This smallest sequence decreases over time $\left(\hat{\theta}_{t+1} < \hat{\theta}_t\right)$ and converges towards $\hat{\theta}_\infty = \theta^{NDC}$.*

A self-financing sequence may not exist. In particular, the above conditions imply

$$\delta(\theta_0 - a_1)\left[1-F(\theta_0)\right] = I.$$

Since $a_1 > 0$, no such sequence exists, even though the NDC is steady state viable, if for example

$$\frac{I}{2\delta} < \theta^m \left[1 - F(\theta^m)\right] < \frac{I}{\delta}.$$

• *Fully discriminatory cooperative.* In each period t, given the access charge a_t, the entry fee E_t and the expected charge a_{t+1} for the next period, types $\theta \geq \theta_t$ join the FDC while types $\theta < \theta_t$ do not, where θ_t is determined by

$$a_t + E_t = (1+\delta)\,\theta_t - \delta a_{t+1}.$$

Now, suppose that at date t, all types $\theta \geq \theta_t$ have joined the FDC and types $\theta < \theta_t$ have not, and consider the date-$(t+1)$ policy. Generation-t old members have unanimous preferences over this policy and will solve

$$\begin{aligned}
&\min_{\{\theta_{t+1}, a_{t+1}, E_{t+1}\}} a_{t+1} \\
&\qquad \text{s.t.} \quad \left[1 - F(\theta_t)\right] a_{t+1} + \left[1 - F(\theta_{t+1})\right](a_{t+1} + E_{t+1}) \geq I \\
&\qquad \text{and} \quad a_{t+1} + E_{t+1} = (1+\delta)\,\theta_{t+1} - \delta a_{t+2}(\theta_{t+1}),
\end{aligned}$$

where $a_{t+2}(\theta_{t+1})$ denotes the optimal access fee that will be set by the new generation in the next period. Clearly, the inequality constraint is binding, so that the value of the program, $a_{t+1}(\theta_t)$, satisfies

$$\begin{aligned}
\left[1 - F(\theta_t)\right] a_{t+1}(\theta_t) &= \min_{\{\theta_{t+1}\}} \left\{I - \left[1 - F(\theta_{t+1})\right]\left[(1+\delta)\,\theta_{t+1} - \delta a_{t+2}(\theta_{t+1})\right]\right\} \\
&= I - \max_{\{\theta_{t+1}\}} \left\{(1+\delta)\left[1 - F(\theta_{t+1})\right]\theta_{t+1} - \delta\left[1 - F(\theta_{t+1})\right] a_{t+2}(\theta_{t+1})\right\} \\
&= R - (1+\delta) \max_{\{\theta_{t+1}\}} \left\{\left[1 - F(\theta_{t+1})\right]\theta_{t+1}\right\},
\end{aligned}$$

where

$$R \equiv (1+\delta)\, I - \delta \max_{\{\theta_{t+2}\}} \left\{\left[1 - F(\theta_{t+2})\right]\left[(1+\delta)\,\theta_{t+2} - \delta a_{t+3}(\theta_{t+2})\right]\right\}$$

does not depend on θ_{t+1}. Generation-t will thus choose θ_{t+1} so as to maximize $\left[1 - F(\theta_{t+1})\right]\theta_{t+1}$

and thus choose[21]

$$\theta_{t+1} = \theta^m.$$

Except in the first period, the membership is the same as for an IOC and users with type $\theta > \theta^m$ get positive surplus $(1+\delta)(\theta - \theta^m)$. The initial membership is however wider than with an IOC, since initial members distribute among themselves the surplus generated by the cooperative $\left(\theta_0^{FDC} < \theta^m\right)$:[22]

Proposition 4.1 *Under user heterogeneity, the investor-owned corporation and the discriminatory cooperative are viable if and only if condition (5) holds. They are then equally inclusive except at the initial stage where the cooperative is more inclusive. The nondiscriminatory cooperative is more inclusive than the other two, but may not be viable.*

4.2 Social optimality

Under heterogeneity, the FDC yields the monopoly membership level. On the other hand, the NDC may not be viable. Let us now consider the Ramsey optimum, defined as the allocation that maximizes the present discounted user surplus:

$$\max_{\{\theta_0, \theta_1 \cdots\}} \int_{\theta_0}^{\infty} \delta\left(\theta - \theta_0\right) f\left(\theta\right) d\theta + \sum\nolimits_{t>0} \delta^t \left[\int_{\theta_t}^{\infty} \left(1+\delta\right)\left(\theta - \theta_t\right) f\left(\theta\right) d\theta\right]$$

$$\text{s.t.} \quad \delta\theta_0 \left[1 - F\left(\theta_0\right)\right] - I + \sum\nolimits_{t>0} \delta^t \left[\left(1+\delta\right)\theta_t \left[1 - F\left(\theta_t\right)\right] - I\right] \geq 0.$$

[21] This is achieved by setting a fixed fee E^m and an access charge a^m such that $a^m + E^m = (1+\delta)\,\theta^m - \delta a^m$ and $(2a^m + E^m)\left[1 - F(\theta^m)\right] = I$, implying that

$$E^m = \frac{1+\delta}{1-\delta}\left[2\theta^m - \frac{I}{1-F(\theta^m)}\right],$$
$$a^m = \frac{1}{1-\delta}\left[\frac{I}{1-F(\theta^m)} - (1+\delta)\,\theta^m\right].$$

[22] θ_0^{FDC} is determined by

$$\delta\theta_0 \left[1 - F\left(\theta_0\right)\right] = I + \delta\left[I - \left[1 - F\left(\theta^m\right)\right]\left(E^m + a^m\right)\right],$$

which leads to:

$$\delta\left\{\theta^m \left[1 - F\left(\theta^m\right)\right] - \theta_0 \left[1 - F\left(\theta_0\right)\right]\right\} = V^m,$$

and thus $\theta_0^{FDC} < \theta^m$ whenever $V^m > 0$.

The maximand reflects the fact that for each generation the net surplus of the marginal user θ_t is equal to zero and therefore the rent of type θ is $(1+\delta)(\theta-\theta_t)$ for $t \geq 1$ and $\delta(\theta-\theta_0)$ for $t=0$. The budget constraint accounts for the equality between the marginal type's gross surplus, $(1+\delta)\theta_t$, and his net intertemporal payment to the cooperative. Unsurprisingly the Ramsey optimum in this stationary context is a constant cutoff, $\theta_t = \theta^R$; each type $\theta > \theta^R$ then gets rent $(1+\delta)\left(\theta-\theta^R\right)$ (or $\delta\left(\theta-\theta^R\right)$ in the first generation). From the budget constraint, the cutoff θ^R is the smallest root of

$$2\delta\theta^R\left[1-F\left(\theta^R\right)\right]=I.$$

The following proposition is proved in the Appendix:

Proposition 4.2 *(i) The Ramsey optimal cooperative has a constant membership ($\theta_t = \theta^R$ for all t).*

(ii) It is more inclusive than the fully discriminatory cooperative and the investor-owned corporation but less inclusive than a steady state nondiscriminatory cooperative (assuming the later can get off the ground).

Comparison with public utility regulation. The Ramsey allocation can be achieved by a leveraged public utility.[23] Two preliminary remarks are in order. First, we will adopt an idealized ("Ramsey-Boîteux") perspective on public utilities; we deliberately ignore the inefficiencies attached to this form of regulation and only aim at a better conceptual understanding of the result obtained above. Second, we have argued that cooperatives have little or no access to external financing because users can easily pay themselves dividends in kind. Public utilities are (highly) leveraged consumer cooperatives. The difference is that public utilities are subject to intensive regulation and to the legal obligation to provide investors with a fair rate of return.

Consider thus a regulated NDC with access to debt financing. Leverage allows the NDC to get off the ground by spreading the initial cost across generations. Suppose for example that

[23] Alternatively, the Ramsey optimum can be achieved by setting an entry fee $E_t = 2(1+\delta)\theta^R$ and by subsidizing usage: $a_t = -\theta^R$. Such a subsidy may trigger moral hazard problems when the input can be used in variable proportions. In order to avoid these problems and, more generally, to avoid usage distortions, a two-part usage tariff should be used – the subsidy should then be applied to the fixed part.

the cooperative is allowed to impute a fair rate of return $(1/\delta - 1)$ on nondepreciated investment to the current access price. That is, since investments are fully depreciated after two periods, the NDC sets $a_0 = 0$ and, at each date $t \geq 1$, an access charge a_t satisfying

$$a_t \left[1 - F(\theta_{t-1}) + 1 - F(\theta_t)\right] = \frac{I}{\delta}.$$

This rate-of-return regulation allows the venture to lever on a permanent basis (borrow I at each date, and reimburse I/δ at the following date). From a financial viewpoint, everything is as if the investment were sunk at the date at which it bears fruits; and so the outcome is then the Ramsey steady state outcome, characterized by $\theta_t = \theta^R$ for every $t \geq 0$ and $a_t = a^R = \theta^R$ for $t \geq 1$.

5 Downstream competition and foreclosure

We have so far assumed that new members do not reduce the value of membership for existing members. This is no longer so if they compete on the same product market. One may therefore wonder whether imposing open access gives rise to a "deregulatory taking." In the case of cooperatives, though, there are no shareholders whose investments in an essential input are expropriated through the increase in competition. Hence, a simple-minded analogy is not warranted and we must therefore conduct a separate analysis.

To simplify this analysis, let us assume that there are only two periods, $t = 0, 1$. N incumbents are present at dates 0 and 1, whereas M potential new users, the entrants, are present at date 1 only. The incumbents initially produce at unit cost c_H. At date 0 they can form a joint venture which at investment cost I develops a new technology. This new technology allows users to produce at unit cost $c_L < c_H$ at date 1. To enter, the entrants need access to the joint venture's technology.

In each period, the n users ($n = N$ or $N+M$) form a symmetric oligopoly (with homogenous or differentiated products). The users' (incumbents', entrants') usage of the technology can be metered, so assessments are levied on each firm's final output. For a symmetric price p charged by the users in the final (downstream) product market, the downstream demand is $q = D_n(p)$.

The symmetric equilibrium price, $p_n(c)$, is assumed to increase with the industry total marginal cost c (which includes the access charge) and to decrease with the number of active participants n. The industry profit $\Pi_n(c)$ and the per firm profit $\pi_n(c) = \Pi_n(c)/n$ are assumed to decrease with the cost c and the number of competitors n. We assume that the investment is socially desirable.

To avoid the use of the joint venture as naked collusive device, we assume throughout this section that cooperatives can charge only linear usage prices: a discriminatory cooperative can still charge different fees to new and old members but dividends are ruled out.[24]

5.1 Closed access

• *Fully discriminatory cooperative.* Suppose that the incumbents can charge a higher usage fee to new members. In this case, the technology de facto remains proprietary to the incumbents, who deny access to entrants:[25] $n = N$. For the cooperative to invest in period 0, it must set a usage fee a^* such that[26]

$$a^* D_N \left[p_N\left(c_H + a^*\right)\right] = I. \tag{6}$$

Each incumbent obtains intertemporal profit

$$\pi_N\left(c_H + a^*\right) + \delta \pi_N\left(c_L\right).$$

Therefore, a fully discriminatory cooperative invests if and only if

$$\pi_N\left(c_H\right) - \pi_N\left(c_H + a^*\right) \leq \delta\left[\pi_N\left(c_L\right) - \pi_N\left(c_H\right)\right],$$

[24] Otherwise, incumbents could maintain high prices (even at the monopoly level) by inflating the usage price charged for the input supplied by the cooperative and sharing the proceeds through dividends, lower entry or franchise fees, etc. Competition authorities are of course aware of this possibility and likely to intervene.

More generally, we assume that the cooperative is not a front for a cartel suppressing competition. There is a wide consensus in the law and economics literature (Baker (1993), Carlton-Salop (1996), Chang *et al.* (1998)) that joint ventures should not facilitate collusion, implement naked price fixing, limit output, prevent offerings of new products, exclude low-cost competitors, and so forth.

[25] We assume here that entrants' products compete substantially with the incumbents' ones; when instead the entrants offer substantially differentiated products, incumbents may choose to grant them some access, although less than what would be efficient – see Rey-Tirole (1997) for an analysis of such partial foreclosure.

[26] We assume for expositional simplicity that $p_N(c_H + a^*)$ is smaller than the monopoly price for the high cost. Otherwise, the incumbents would want to finance some of the investment in a lump-sum fashion. Our analysis is easily generalized to this alternate case.

or, using (6):

$$I \leq [p_N (c_H + a^*) - c_H] D_N [p_N (c_H + a^*)] - [p_N (c_H) - c_H] D_N [p_N (c_H)] + \delta [\Pi_N (c_L) - \Pi_N (c_H)] .$$

The left-hand side represents the cost of investment. The discounted term on the right-hand side represents the increase in profits generated by the investment in period 1, taking into account that part of the decrease in cost will be passed through to consumers ($p_N (c_L) < p_N (c_H)$). The nondiscounted terms on the right-hand side reflect the impact of the usage fee on the period-0 price: Because the usage fee is partially passed through to consumers ($p_N (c_H + a^*) > p_N (c_H)$), period-0 profits decrease by less than I.

The overall impact of the investment on the incumbents' profits is ambiguous and depends in particular on the extent to which costs changes are passed through to consumers, as well as on consumers' demand elasticity.[27] Provided that an industry-wide increase in cost reduces profits, incumbents' incentives are driven by a tradeoff between the loss from the higher cost generated by the surcharge a needed to cover the investment in period 0, and the benefit from a lower cost in period 1. It can be checked that *for small innovations* (I and $c_H - c_L$ small), *the incumbents invest whenever the social value of the investment in a closed cooperative*, given by $\delta (c_H - c_L) D_N [p_N (c_H)] - I$, *is positive.*[28] However, as we will see, the surcharge imposed at date 0 to recover the investment cost distorts the price structure In addition, the level of the prices is determined by the degree of imperfect competition and thus may not coincide with the socially optimal one. As a result, for large innovations the private and social incentives to invest are no longer always aligned.

• *Investor-owned corporation.* Suppose next that the new technology is produced by an IOC. In the absence of restrictions on the licencing agreements, the IOC makes the industry monopoly

[27]For example, in the standard Hotelling duopoly with inelastic total demand and consumers uniformly distributed between the two firms, prices fully adjust to costs: $p_N (c) = c + t$, where the parameter t reflects the degree of differentiation between the two incumbents. The incumbents are then indifferent as to whether to invest, since any change in the industry cost is entirely passed through to consumers, with no impact on the profits.

[28]The impact of the investment on the industry profit is in that case approximately equal to

$$\Pi'_N (c_H) [-a^* + \delta (c_H - c_L)] \simeq \frac{\Pi'_N (c_H)}{D_N [p_N (c_H)]} [-I + \delta (c_H - c_L) D] .$$

profit. For example, in the case of an homogenous product, it could offer a fixed fee equal to what a monopolist in the market would be willing to pay.[29] As a result, the price level is higher than in the case of an FDC.[30]

5.2 Open access

A cooperative's incumbents have less incentive to invest under open access, because the benefits of the investment are at least partially *competed away* by the new entrants. More precisely, in a nondiscriminatory cooperative the incumbents choose to invest if the short-term cost of the investment:

$$\pi_N(c_H) - \pi_N(c_H + a^*),$$

is lower than the long-term benefit:

$$\delta\left[\pi_N(c_L) - \pi_N(c_H)\right]$$

in the case of an FDC and lower than

$$\delta\left[\pi_{N+M}(c_L) - \pi_{N+M}(c_H)\right]$$

in the case of an NDC. Letting $g_n = \pi_n(c_L) - \pi_n(c_H)$ denote the impact of the innovation on per firm profits, incumbents have less incentive to invest under open access provided that

$$g_{N+M} < g_N.$$

One would in general expect g_n to decrease with n. A sufficient condition for this to be the case is that the sensitivity of individual profits $|\pi_n'|$ decreases with n. This sufficient condition is satisfied in the standard Cournot oligopoly models with homogenous products (e.g., linear or constant-elasticity demand)[31] and in the standard models of competition with differentiated

[29] Alternatively, it could license the new technology to all incumbents but append an exclusive-licensing-within-the-territory provision.

[30] If foreclosure is possible but nonlinear pricing is ruled out, an IOC may furthermore create additional inefficiencies through double-marginalization problems. See Hart-Moore (1998) for an analysis of this issue.

[31] In that case, even the industry-wide gain $G_n = ng_n$ decreases with n. Cournot industry profits are equal to $\Pi_n(c) = \frac{n(d-c)^2}{(n+1)^2}$ in the case of a linear demand $D(p) = d - p$ and to $\Pi_n(c) = \frac{(n\eta-1)^{\eta-1}}{(n\eta)^{\eta}c^{\eta-1}}$ in the case

products.[32] Last, in the extreme case where new entrants drive the price down to its competitive level ($p_{N+M}(c)$ close to c for $c = c_L, c_H$), incumbents have no incentive to invest since date-1 profits vanish anyway under the pressure of entry.[33]

The comparison between an FDC and an NDC points at the following tradeoff. Nondiscriminatory ventures grant open access to new entrants and thus, for given costs, generate prices that are closer to the first-best level: $c \leq p_{N+M}(c) < p_N(c)$. However, open access may discourage incumbents from investing in new technologies, in which case the cost c_1 is higher (c_H instead of c_L). Open access (NDC) would thus be optimal absent investment considerations, but closed access (FDC) may be preferable in order to encourage innovation:

of a constant-elasticity demand $D(p) = p^{-\eta}$. In both cases, $|\Pi'_n|$ and thus G_n decrease with n, and g_n decreases even more rapidly since the incumbents must share the benefit fm the innovation with the new users: $\frac{g_{N+M}}{g_N} = \frac{N}{N+M}\frac{G_{N+M}}{G_N} < \frac{G_{N+M}}{G_N}$.

[32]With product differentiation, total demand may increase when the number of firms and thus the available choice of products increases. As a result, the *industry-wide* gain $G_n = ng_n$ may increase in n.

Suppose for example that n firms and a unit mass of consumers are uniformly distributed on a unit circle, and that in addition each firm has a "backyard" demand: a mass d of consumers distributed along a segment of length l between the firm and an outside option $\bar{p}$. With quadratic costs of the form tx^2, when the other firms charge the same price p^e the demand for firm i is given by (focussing on interior configurations where the backyard demand is partially satisfied):

$$\frac{1}{n} + \frac{n(p^e - p_i)}{2t} + \left(1 + \frac{\bar{p} - p_i}{tl^2}\right)\frac{d}{2}.$$

The equilibrium individual profits are then equal to

$$\pi_n(c) = \frac{n + d/2l^2}{(n + d/l^2)^2 t}\left[\left(\frac{1}{n} + \frac{d}{2}\right)t + \frac{d}{2l^2}(\bar{p} - c)\right].$$

Thanks to the increased choice of products, $|\Pi'_n|$ and G_n increase with n; however, the sensitivity of *individual profit* to cost changes $|\pi'_n|$, and thus g_n, still decrease with n.

In contrast, consider the case of a linear demand which, building on Dixit (1986), depends only on p_i and the average price $\bar{p} = \frac{1}{n}\Sigma_j p_j$, and suppose further that total demand is normalized so as not to increase with n ($\Sigma_i D_i = d - a\bar{p}$):

$$D_i = \frac{d - ap_i}{n} - b(p_i - \bar{p}).$$

[This particular formulation further ensures that the equilibrium is stable for any n whenever $b < 2a$ – see Dixit (1986).] Industry profit is then given by

$$\Pi_n(c) = \frac{a + (n-1)b}{(2a + (n-1)b)^2}(d - ac)^2.$$

so that $|\Pi'_n|$, G_n and g_n all decrease with n.

[33]More generally, as long as entry drives per-firm profit down to 0, for any N $g_{N+M} < g_N$ for M large enough.

Proposition 2 *(i) For a given investment level, open access, nondiscriminatory cooperatives generate higher social welfare than closed access, fully discriminatory ones.*

(ii) If, as is the case in standard oligopoly models, industry cost reductions benefit individual firms more, the lower the number of participants (that is, $\pi_n(c_L) - \pi_n(c_H)$ decreases with n for $c_L < c_H$), then nondiscriminatory cooperatives are less conducive to investment and may generate a lower welfare than fully discriminatory ones.

The only result in Proposition 2 that has not yet been established (that on welfare comparisons) is proven in Appendix C.

5.3 Ramsy optimality for cooperatives

Since the benefits from investment are competed away in an open access joint venture, an optimal regulation may allow for some limitation on new users' access. This limitation can take the form of a discrimination between old and new members at a given time (entry fee, seniority-based usage fees, dividends, etc.). Alternatively, and to the extent that a regulated cooperative has access to credit, the venture could borrow in order to backload the impact of investment. For example, the regulator could allow the cooperative to borrow so as to cover its investment needs; the cooperative would not need to impose any surcharge at date 0 and would set a date-1 usage fee a_1^* so as to reimburse the loan:[34]

$$\delta a_1^* D_{N+M}(p_{N+M}(c_L + a_1^*)) = I.$$

[34] If the old technology is freely available to new entrants, the date-1 cost $c_1 = c_L + a_1$ cannot exceed c_H, which further restricts the viability of the cooperative. For example, suppose that initially there is one incumbent ($N = 1$) and that entrants compete à la Bertrand with homogenous product; in the absence of the innovation, prices would thus be respectively $p_1(c_H)$ and c_H at dates 0 and 1 and the incumbent would overall obtain $\pi_1(c_H)$ – which, with homogenous product, is the maximal industry profit for date 0. Then, the constraint $c_1 \leq c_H$ is binding (thus making the joint venture nonviable) even though the investment is socially desirable when:

i) $S(p_0^R) + \delta S(p_1^R) > S(p_1(c_H)) + \delta S(c_H)$
where the Ramsey prices (p_0^R, p_1^R) satisfy $p_0^R < p_1(c_H)$, $p_1^R > c_L$ and

$$(p_0^R - c_H)D(p_0^R) + \delta(p_1^R - c_L)D(p_1^R) = \pi_1(c_H) + I$$

ii) but $\bar{p}_1 > c_H$, where $\bar{p}_1$ is the "date 1- constrained Ramsey" price, such that

$$\delta(\bar{p}_1 - c_L)D(\bar{p}_1) = I.$$

Equilibrium prices are then $p_0^{LC} = p_N(c_H)$ and $p_1^{LC} = p_{N+M}(a_1^* + c_L)$, where "LC" stands for "levered cooperative"; the intertemporal price structure thus depends on the evolution of competition (N competitors in period 0, versus $N + M$ in period 1) and on the magnitude of investment cost (which in effect is fully supported in period 1).[35]

More generally, the (Ramsey) social optimum depends on the regulatory toolkit. Because we are interested in competition policy, we focus on regulatory intervention that a) mandates open access, while b) allowing discrimination between old and new members (through leverage, differentiated access charges, entry fees, dividends, etc.), so as to yield any desired burden shifting between incumbents and new entrants. [This regulation could further be compared to the optimal regulation with closed access.]

Let $S_n(p)$ denote the consumers' net surplus, with $S_n'(p) = -q$. The benchmark allocation thus solves

$$\max_{\{p_0,p_1\}} \sum_{t=0,1} \delta^t \left[S_{n_t}(p_t) + (p_t - c_t)D_{n_t}(p_t)\right] - I$$

$$\text{s.t.} \quad \sum_{t=0,1} \delta^t (p_t - c_t)D_{n_t}(p_t) - I \geq \bar{\Pi},$$

with $c_0 = c_H$, $c_1 = c_L$, $n_0 = N$ and $n_1 = N + M$. $\bar{\Pi}$ denotes the firms' aggregate reservation level of profit;[36] $\bar{\Pi} = 0$ would correspond to the social optimum subject to the industry's break-even constraint, but other levels of $\bar{\Pi}$ may be more relevant in practice, depending on who controls access to the old technology. For example, if only the incumbents have access to the old technology, $\bar{\Pi}$ should account for the profit they could achieve without investing: $\bar{\Pi} = \Pi_N(c_H) + \delta N \pi_{N+M}(c_H)$; in other contexts, $\bar{\Pi}$ may also include the profit that new entrants could achieve with the old technology.

[35] When such borrowing still induces excessive prices in the initial period, the regulator may allow the cooperative to overleverage itself (i.e., borrow more than I) in order to further encourage the incumbents to lower their initial prices. This policy needs however to be closely supervised, since: (i) the incumbents would "overleverage" the venture as much as possible, in order to benefit from the largest subsidy in the first period; and (ii) they would rather distribute to themselves the resulting subsidy in a lump-sum manner than through a subsidy in the usage fee, in order to maintain high prices in the first period.

[36] Only this "aggregate participation constraint" is relevant given the feasability of discrimination between incumbents and entrants; for example, differentiated access charges, or nondifferentiated access charges together with an entry fee for new entrants, would allow to meet each of the incumbents' and the entrants' participation constraints whenever this aggregate participation constraint is satisfied.

Letting λ denote the shadow price of the profit constraint, the "Ramsey optimum" satisfies

$$\frac{p_t^R - c_t}{p_t^R} = \frac{\lambda}{1+\lambda} \frac{1}{\eta_{n_t}(p_t^R)}, \tag{7}$$

where $\eta_n(p) \equiv -[dD_n/dp]/[D_n/p]$ denotes the elasticity of demand.

The optimal price structure is likely to involve some frontloading, since the intertemporal cost structure is itself tilted.[37] However, comparing condition (7) with the equivalent conditions for NDCs and FDCs suggests that both forms of cooperatives generate a price structure that is more frontloaded than the Ramsey structure, because the date-0 price is based on an inflated cost, $c_H + a^*$; in addition, the price structure is even more distorted for NDCs than for FDCs, because of the increased competitive pressure at date 1 in the case of NDCs.

To see this most clearly, consider the case where all firms compete à la Cournot with the same homogenous product, for which the demand has a constant elasticity (that is $D_n(p) = p^{-\eta}$). Then:

$$\begin{aligned}
\frac{p_0^R}{c_H} &= \frac{p_1^R}{c_L} = \frac{1}{1 - \frac{\lambda}{1+\lambda}\frac{1}{\eta}}, \\
\frac{p_0^{FDC}}{c_H + a^*} &= \frac{p_1^{FDC}}{c_L} = \frac{1}{1 - \frac{1}{N\eta}}, \\
\frac{p_0^{NDC}}{c_H + a^*} &= \frac{1}{1 - \frac{1}{N\eta}}, \frac{p_1^{NDC}}{c_L} = \frac{1}{1 - \frac{1}{(N+M)\eta}}.
\end{aligned}$$

And so:

$$\frac{p_0^{NDC}/c_H}{p_1^{NDC}/c_L} > \frac{p_0^{FDC}/c_H}{p_1^{FDC}/c_L} > \frac{p_0^R/c_H}{p_1^R/c_L} = 1.$$

Allowing the regulated cooperative to borrow tends to limit frontloading. For example, for the "fully levered" cooperative described at the beginning of this section, prices are given by:

$$\frac{p_0^{LC}}{c_H} = \frac{1}{1 - \frac{1}{N\eta}}, \frac{p_1^{NDC}}{c_L + a_1^*} = \frac{1}{1 - \frac{1}{(N+M)\eta}}$$

[37] If for example the products are homogenous ($D_n(p) = D(p)$), a revealed preference argument applied to the per-period Lagrangian $S(p_t) + \lambda(p_t - c_t) D(p_t)$, together with $c_1 < c_0$, implies $p_1 < p_0$.

and thus

$$\frac{p_0^{LC}/c_H}{p_1^{LC}/c_L} < \frac{p_0^{NDC}/c_H}{p_1^{NDC}/c_L}.$$

An appropriate amount of leverage can replicate the optimal price structure. Note however that the overall price level remains determined by the degree of (imperfect) competition and thus need not coincide with the Ramsey level. The following proposition summarizes the analysis:

Proposition 3 *For a Cournot oligopoly with homogenous product and constant-elasticity demand, the assessment surcharge levied by a nonlevered cooperative to cover the investment cost distorts the pricing structure, and makes the cooperative more frontloaded than is socially optimal; the closed access, fully discriminatory cooperative generates less frontloading than the open access, nondiscriminatory cooperative; frontloading is reduced (and may be eliminated or even reversed) in the case of a leveraged cooperative.*

6 Conclusion

Potential members knocking at the door of a successful joint venture always feel slighted when offered discriminatory treatment or being excluded altogether. This paper has analyzed their concern and identified two potential sources of inefficiency arising from discriminatory treatment. The first is that, in a natural monopoly situation, incumbent members have an incentive to exploit their monopoly power; the resulting taxation of new membership leads to underinclusiveness (section 4). The second source of inefficiency is due to the incumbents' incentive to restrict entry into their downstream markets by new players (section 5).

This suggests that, in natural monopoly situations,[38] joint ventures ought to be viewed as "essential facilities" and forced to treat users equally. Our analysis however calls for some

[38] If returns to scale are moderate beyond some minimal scale, facilities duplication may substitute favorably for a necessarily imperfect regulation of access. This point was for example made forcefully by Advocate General Jacobs in Oscar Bronner vs Mediaprint (European Court of Justice 1998). Mediaprint (with downstream market share of 47%) operated its own newspaper delivery system in Austria, and refused to give access to a competing newspaper, Der Standard (market share 3.6%), on the same terms as a noncompeting, independent newspaper that used the delivery system.The Advocate General expressed his concerns that an access policy, while encouraging competition in the short run, would kill incentives for small newpapers to develop their own delivery system (possibly cooperatively) and thereby prevent facilities-based competition in the long term.

caution, at least at a general level. Nondiscriminatory cooperatives are highly fragile institutions. For one thing, they imply that new members free ride on the investment of established members (had we introduced uncertainty, free riding might have been even more of an issue as potential members could join the joint venture only if it turns successful). This induces underinvestment (the horizon problem) or even prevents the cooperative from getting off the ground. Furthermore, even if it is viable on a stand-alone basis, the nondiscriminatory cooperative is vulnerable to attacks by discriminatory cooperatives or by for-profits, which can lure potential members through the promise of future natural monopoly profits. For another thing, in a situation in which new members compete with established ones on the product market, the nondiscriminatory cooperative may be reluctant to levy assessments that reduce the latter's current profit in order to finance an innovation whose benefit will be competed away. While the new members' concerns are real, these aspects should be seriously taken into account before forcing open access to a joint venture. In a nutshell, open access policies involve a familiar Schumpeterian tradeoff between static efficiency and innovation. Last, future research should aim at helping policymakers to define an "organizationally neutral" competition policy.[39] The treatment of access to cooperatives should be consistent with the essential facilities doctrine applied to investor-owned corporations, and not tilt the level-playing field in favor of a specific organizational form.

[39] The organizational neutrality problem has been recognized at least since Associated Press (*Associated Press II*, 326 US 1943). The US Supreme Court affirmed a lower court decision and sided with the government challenge of AP's bylaws. Dissenting Justices however noted that AP's two proprietary competitors, United Press and International News Service, were able to enforce unchallenged similar restraints as those implied by AP's bylaws in their contracts with subscribers.

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Appendix

A Proof of Lemma 4.1

Consider two self-financing sequences $\Theta^1 = (\theta_0^1, \theta_1^1, \cdots)$ and $\Theta^2 = (\theta_0^2, \theta_1^2, \cdots)$; by definition, they must satisfy, for $i = 1, 2$

$$\delta\theta_0^i = \left[\frac{1}{1-F(\theta_0^i)} + \frac{\delta}{1-F(\theta_0^i)+1-F(\theta_1^i)}\right] \qquad (C_0^i)$$

and for $t = 1, 2, ...$

$$(1+\delta)\theta_t^i \geq \left[\frac{1}{1-F(\theta_{t-1}^i)+1-F(\theta_t^i)} + \frac{\delta}{1-F(\theta_t^i)+1-F(\theta_{t+1}^i)}\right] I. \qquad (C_t^i)$$

Now, for each $t = 0, 1, ...$, choose $i(t)$ such that $\theta_t^{i(t)} = \min(\theta_t^1, \theta_t^2)$. Then for any $t > 0$, $\left(C_t^{i(t)}\right)$ implies

$$\begin{aligned}(1+\delta)\min(\theta_t^1, \theta_t^2) &= (1+\delta)\theta_t^{i(t)} \geq \left[\frac{1}{1-F(\theta_{t-1}^{i(t)})+1-F(\theta_t^{i(t)})} + \frac{\delta}{1-F(\theta_t^{i(t)})+1-F(\theta_{t+1}^{i(t)})}\right] I \\ &\geq \frac{I}{1-F(\min(\theta_{t-1}^1, \theta_{t-1}^2))+1-F(\min(\theta_t^1, \theta_t^2))} \\ &\quad + \frac{\delta I}{1-F(\min(\theta_t^1, \theta_t^2))+1-F(\min(\theta_{t+1}^1, \theta_{t+1}^2))},\end{aligned}$$

(and similarly for $t = 0$), which establishes that the sequence $\Theta^1 \bigwedge \Theta^2 = \left(\min(\theta_0^1, \theta_0^2), \min(\theta_1^1, \theta_1^2), \cdots\right)$ is self-financing. This, in turn, ensures that if there exists a self-financing sequence, there exists a smallest one, which we denote by $\hat{\Theta} = \left(\hat{\theta}_0, \hat{\theta}_1, ...\right)$. Furthermore, this smallest self-financing sequence must be such that all constraints are binding (otherwise, it would be possible to reduce the first $\hat{\theta}_t$, say, for which the corresponding constraint is not binding):

$$\delta\theta_0 = \left[\frac{1}{1-F(\theta_0)} + \frac{\delta}{1-F(\theta_0)+1-F(\theta_1)}\right] \qquad (C_0)$$

and for all $t > 1$

$$(1+\delta)\theta_t = \left[\frac{1}{1-F(\theta_{t-1})+1-F(\theta_t)} + \frac{\delta}{1-F(\theta_t)+1-F(\theta_{t+1})}\right] I. \qquad (C_t)$$

We now show that the sequence $\hat{\Theta}$ satisfies $\hat{\theta}_t \geq \hat{\theta}_{t+1}$. Suppose that it is not the case and define τ as the first date t such that $\hat{\theta}_t < \hat{\theta}_{t+1}$. Consider the sequence Θ' such that $\theta'_t = \hat{\theta}_t$ for $t \leq \tau$, $\theta'_{\tau+1} = \hat{\theta}_\tau$, and $\theta'_t = \hat{\theta}_{t-1}$ for $t \geq \tau + 1$. By construction, this sequence satisfies (C_t) for any $t \leq \tau - 1$ (the condition (C_t) is then unchanged) and for $t \geq \tau + 2$ (the new condition (C'_t) then corresponds to the previous condition (C_t)). Furthermore, it satisfies (for the sake of presentation, we suppose $\tau > 0$, but the reader can check that the argument applies as well to the case $\tau = 0$):

$$
\begin{aligned}
(1+\delta)\theta'_\tau &= (1+\delta)\hat{\theta}_\tau = \left[\frac{1}{1-F(\hat{\theta}_{\tau-1})+1-F(\hat{\theta}_\tau)} + \frac{\delta}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_{\tau+1})}\right] I \\
&> \left[\frac{1}{1-F(\hat{\theta}_{\tau-1})+1-F(\hat{\theta}_\tau)} + \frac{\delta}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_\tau)}\right] I \\
&= \left[\frac{1}{1-F(\theta'_{\tau-1})+1-F(\theta'_\tau)} + \frac{\delta}{1-F(\theta'_\tau)+1-F(\theta'_{\tau+1})}\right] I, \mathrm{C}'_\tau
\end{aligned}
\tag{8}
$$

where the inequality derives from $\hat{\theta}_\tau < \hat{\theta}_{\tau+1}$, and

$$
\begin{aligned}
(1+\delta)\theta'_{\tau+1} &= (1+\delta)\hat{\theta}_\tau = \left[\frac{1}{1-F(\hat{\theta}_{\tau-1})+1-F(\hat{\theta}_\tau)} + \frac{\delta}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_{\tau+1})}\right] I \\
&\geq \left[\frac{1}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_\tau)} + \frac{\delta}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_{\tau+1})}\right] I \\
&= \left[\frac{1}{1-F(\theta'_\tau)+1-F(\theta'_{\tau+1})} + \frac{\delta}{1-F(\theta'_{\tau+1})+1-F(\theta'_{\tau+2})}\right] I, \mathrm{C}'_{\tau+1}
\end{aligned}
\tag{9}
$$

whereas the inequality stems from $\hat{\theta}_{\tau-1} \geq \hat{\theta}_\tau$. It follows that the sequence Θ' is self-financing; but then, $\hat{\Theta}' = \hat{\Theta} \bigwedge \Theta'$ is also self-financing and satisfies $\hat{\theta}'_t \leq \hat{\theta}_t$ for any t and $\hat{\theta}'_{\tau+1} = \hat{\theta}_\tau < \hat{\theta}_{\tau+1}$, so that $\hat{\Theta}$ was not the smallest self-financing sequence.

Next, we show that the sequence satisfies $\hat{\theta}_t > \hat{\theta}_{t+1}$. Suppose that it is not the case. Given the above argument, $\hat{\theta}_t$ must therefore remain constant over several periods. Define τ as the first date t such that $\hat{\theta}_t = \hat{\theta}_{t+1}$ and T as the first date $t > \tau$ such that $\hat{\theta}_t < \hat{\theta}_\tau$. Consider the sequence Θ' such that $\theta'_t = \hat{\theta}_t$ for $t \leq \tau$ and $\theta'_t = \hat{\theta}_{t+T-\tau-1}$ for $t \geq \tau+1$. As before, this sequence satisfies (C_t) for any $t \leq \tau - 1$ (the condition (C_t) is again unchanged) and for $t \geq \tau + 2$ (the new condition (C'_t) then corresponds to the previous condition $(C_{t+T-\tau-1})$). Furthermore, it satisfies (assuming again $\tau > 0$ for the sake of presentation):

$$\begin{aligned}(1+\delta)\theta'_\tau &= (1+\delta)\hat{\theta}_\tau \geq \left[\frac{1}{1-F(\theta'_{\tau-1})+1-F(\theta'_\tau)} + \frac{\delta}{1-F(\theta'_\tau)+1-F(\theta'_{\tau+1})}\right] I \\ &= \left[\frac{1}{1-F(\hat{\theta}_{\tau-1})+1-F(\hat{\theta}_\tau)} + \frac{\delta}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_T)}\right] I, \mathrm{C}'_\tau\end{aligned}$$

(10)

$$\begin{aligned}(1+\delta)\theta'_{\tau+1} &= (1+\delta)\hat{\theta}_T \geq \left[\frac{1}{1-F(\theta'_\tau)+1-F(\theta'_{\tau+1})} + \frac{\delta}{1-F(\theta'_{\tau+1})+1-F(\theta'_{\tau+2})}\right] I \\ &= \left[\frac{1}{1-F(\hat{\theta}_\tau)+1-F(\hat{\theta}_T)} + \frac{\delta}{1-F(\hat{\theta}_T)+1-F(\hat{\theta}_{T+1})}\right] I, \mathrm{C}'_{\tau+1}\end{aligned}$$

(11)

where the first inequality derives from (C_τ) and $\hat{\theta}_{\tau+1} = \hat{\theta}_\tau > \hat{\theta}_T$, whereas the second inequality stems from (C_T) and $\hat{\theta}_{T-1} = \hat{\theta}_\tau$. Therefore, Θ' and $\hat{\Theta}' = \hat{\Theta} \bigwedge \Theta'$ are both self-financing sequences; but $\hat{\theta}'_t \leq \hat{\theta}_t$ for any t and $\hat{\theta}'_{\tau+1} = \hat{\theta}_T < \hat{\theta}_{\tau+1}$, so that $\hat{\Theta}$ was not the smallest self-financing sequence.

The smallest sequence $\hat{\Theta}$ is thus strictly decreasing over time. Since it is bounded below by $\theta = 0$, it converges towards a value $\hat{\theta}_\infty$ which, by continuity, must satisfy

$$(1+\delta)\hat{\theta}_\infty = \left[\frac{1}{1-F(\hat{\theta}_\infty)+1-F(\hat{\theta}_\infty)} + \frac{\delta}{1-F(\hat{\theta}_\infty)+1-F(\hat{\theta}_\infty)}\right] I,$$

that is,

$$2\left[1-F(\hat{\theta}_\infty)\right]\hat{\theta}_\infty = I.$$

Hence, $\hat{\theta}_\infty = \theta^*$.

B Proof of Proposition 4.2

(i) The concavity of the revenue function $\theta\left[1-F\left(\theta\right)\right]$ ensures that the Ramsey program, too, is concave. Denoting by λ the Lagrange multiplier associated with the budget constraint, for $t\geq 0$ the first-order condition is

$$\theta_t\frac{f\left(\theta_t\right)}{1-F\left(\theta_t\right)}=1-\frac{1}{\lambda},$$

and thus θ_t must be constant, since the left-hand side is increasing.

(ii) The budget constraint then ensures that θ^R is the lowest root of

$$\begin{aligned} 0 &= \delta\theta\left[1-F\left(\theta\right)\right]-I+\sum_{t>0}\delta^t\left[\left(1+\delta\right)\theta\left[1-F\left(\theta\right)\right]-I\right] \\ &= \left[\delta+\sum_{t>0}\delta^t\left(1+\delta\right)\right]\theta\left[1-F\left(\theta\right)\right]-\sum_{t\geq 0}\delta^t I \\ &= \frac{1}{1-\delta}\left[2\delta\theta\left[1-F\left(\theta\right)\right]-I\right], \end{aligned}$$

or

$$2\theta^R\left[1-F\left(\theta^R\right)\right]=\frac{I}{\delta}.$$

Hence θ^R lies between θ^{NDC} (the smallest root of $2\theta\left[1-F\left(\theta\right)\right]=I<\frac{I}{\delta}$) and θ^m (which maximizes $\theta\left[1-F\left(\theta\right)\right]$).

C Proof of Proposition 2

More precisely, letting $W_N\left(c\right)$ denote the welfare arising from competition among N firms with cost c and $a^*\left(I\right)$ denote the access charge defined by (6), closed access yields

$$W_1^{FDC}=W_N\left(c_H+a^*\left(I\right)\right)+\delta W_N\left(c_L\right)$$

if the investment cost is small enough, that is, if $I<\bar{I}^{FDC}$ such that

$$\pi_N\left(c_H\right)-\pi_N\left(c_H+a^*\left(\bar{I}^{FDC}\right)\right)=\delta\left[\pi_N\left(c_L\right)-\pi_N\left(c_H\right)\right],$$

and

$$W_0^{FDC} = (1+\delta) W_N(c_H)$$

if $I > \bar{I}^{FDC}$. In contrast, open access yields

$$W_1^{NDC} = W_N(c_H + a^*(I)) + \delta W_{N+M}(c_L)$$

if $I < \bar{I}^{NDC}$ such that

$$\pi_N(c_H) - \pi_N\left(c_H + a^*\left(\bar{I}^{NDC}\right)\right) = \delta\left[\pi_{N+M}(c_L) - \pi_{N+M}(c_H)\right],$$

and

$$W_0^{NDC} = W_N(c_H) + \delta W_{N+M}(c_H)$$

if $I > \bar{I}^{NDC}$.

As long as competition drives prices closer to cost, $W_h^{NDC} > W_h^{FDC}$ for $h = \{0, 1\}$. And provided that g_n decreases with n, FDCs are more conducive to investment: $\bar{I}^{NDC} < \bar{I}^{FDC}$. Thus, assuming that the cooperative never has an excessive incentive to invest, we have:

- open access is preferable to closed access when either the investment cost is very small $\left(I < \bar{I}^{NDC}\right)$, since in that case open access does not preclude innovation, or when it is very large $\left(I > \bar{I}^{FDC}\right)$, since in that case investment is never made anyway.

- closed access may be preferable to open access for intermediate values of the investment cost $\left(\bar{I}^{NDC} < I < \bar{I}^{FDC}\right)$, for which closed access is necessary to ensure investment. In that case, one has to trade off the benefit of the innovation against that of competition. For example, when the innovation is small ($c_H - c_L$, and thus $\bar{I}^{FDC}$ and $\bar{I}^{NDC}$ are close to 0), open access dominates closed access in the range $I \in \left[\bar{I}^{FDC}, \bar{I}^{NDC}\right]$. In contrast, assuming that welfare $W_n(c)$ converges to $W_\infty(c)$ at least as fast as $1/n$,[40] then for

[40] This is the case for Hotelling models (with linear or convex transportation costs) and for usual Cournot models with homogenous products (see Vives (2000), p. 110); for example, $W_n \sim \left(1 - \frac{1}{2n}\right) W_\infty$ when demand is linear and $W_n \sim \left(1 - \left(1 - \frac{1}{\eta}\right)\frac{1}{n^2}\right) W_\infty$ when demand has constant elasticily η.

$I \in \left[\bar{I}^{FDC}, \bar{I}^{NDC}\right]$ closed access dominates open access when N is large enough.[41]

[41] A sufficient condition is

$$W_{N+M}(c_H) - W_N(c_H) < W_N(c_L) - W_N(c_H),$$

where the left-hand side goes to zero (while the right-hand side converges towards $W_\infty(c_L) - W_\infty(c_H) > 0$) when N and thus $N + M$ go to infinity.