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On the Management of Research Collaborations: Which Form of Governance?

Claudio Panico, Bocconi University and KITeS

claudio.panico@unibocconi.it

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Abstract

The management of research collaborations is challenging in many respects. The research efforts are hardly *verifiable* and it is not possible to contract for a clearly defined research output. The parties *negotiate* to allocate the resulting gains and may also decide to *break up* the collaboration and proceed separately. All this poses big governance challenges. On the other hand, contractual forms of collaborations have become increasingly more common, specially in high-tech industries. Formal contracts give birth to a large variety of forms of governance by specifying ownership patterns and configurations of control.

In this paper, we set up a simple yet comprehensive framework to develop a normative analysis of the management of research collaborations. We study a large company contracting with a small and cash constrained research unit. While having no bargaining power ex ante, when the collaboration starts, the unit can be endowed by the company with a *fraction of ownership and a fraction of control rights* to ameliorate its bargaining position when negotiating ex post.

We solve the company's *governance design problem* when: i) the unit's research effort is verifiable, and hence contractible, or not, and ii) when the collaboration is *stable*, meaning that the parties always prefer to share the continuation surplus, or *unstable*, allowing for the possibility of break -up. Our analysis shows how and why the best form of governance becomes increasingly more complex in more contractually difficult environments.

Keywords: research collaborations, governance, complete and incomplete contracts, ownership, control.

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*NOT QUITE PRELIMINARY YET STILL INCOMPLETE. Comments, discussion and interpretation of the results to be extended.

1 Introduction

The formation rate of R&D partnering has increased enormously in the last two decades with a shift from joint ventures toward more flexible forms of collaborations. This is specially true in high-tech industries where we observe a relative increase in the number of *contractual forms* of collaborations. Following this trends, different empirical works have analyzed the contractual environment of research. The determinants of the allocation of ownership and control rights are studied, testing as well the main theoretical prescriptions.[1]

Starting from the findings of the empirical literature and building on the literature in contract theory, we advance a simple yet comprehensive model that accounts for the salient features of contracts in research collaborations. Research contracts are incomplete and the parties must negotiate at a later stage to share the value created. We argue that ownership and control rights contribute in different ways to set the boundaries of the negotiation. Therefore, the most crucial aspect to be addressed when starting the collaboration is how such rights should be allocated between the parties. Our analysis sheds a light on how to do so.

We target a large company with deep pocket contracting with a small and cash constrained research unit. We make this choice because the most detailed empirical studies are concerned with collaborations in the biopharmaceutical industry between a small biotech firm and a large pharma company. Second, the asymmetries between the parties provide a justification for some of the assumptions that we make to set clearly the contours of the

[1] We discuss the different streams of literature in section 2.

contracting environment. And related to this last point„our attention is really devote to research projects in the earliest stage, when it is most difficult to specify the research outcome and to verify the research efforts.

1.1 Preliminaries

We reduce the company's problem to manage the collaboration to the design of the contractual governance. Before illustrating the formal model, we discuss the main aspects of contracting that we try to embed in our analysis as well as our main findings.

Research contracts. Designing contracts for research is challenging in many respects. Outside the realm of research, contracts specify many aspects: the quality and the quantity of the good to be exchanged, the price, the specific investments to be made, the timing, possible penalties, etc. Instead, research contracts are by definition incomplete. The efforts of the parties are hardly verifiable and the uncertainty over technological shocks of different kind precludes writing a contract for the delivery of a clearly defined research output. For the same reason, it is hard to specify beforehand how to proceed after some preliminary research has been done and the shocks have realized.

The contracting efforts may also not be justified as many collaborations fail to deliver any result, or else they may be interrupted. The parties could then wait for the moment when decisions have been made and the uncertainty is (partly) resolved, and then negotiate to decide the destiny of the collaboration. Depending on the situation, the negotiation outcome can entail either continuation with a sharing of the *surplus*, or *break up*, with the parties taking their *outside options*.

But research contracts are quite detailed when it comes to allocate different categories of rights. Formal contracts define the ownership pattern, for example allocating the intellectual property rights (IPRs) over research outcomes. These are critical assets for small firms and in fact their allocation is one of the main focus of initial contracting. Such rights can be allocated to only one party or there can be joint ownership, such as in the case of co-assigned patents. Second, research contracts also refer to a category of rights that do not refer to ownership and that we broadly define *control rights*. They can specify the use of assets and patents, or else who has the right to make certain decisions during research and when negotiating. Examples of such rights are the right to expand the breadth of the collaboration, to terminate or shelve particular projects, etc.

Main ingredients of the model. We advance a framework that accounts for the aspects described above and model how the ex ante allocation of ownership and control rights influences negotiation. We build on the insights from two branches of contract theory: agency theory and property-rights (PR) economics.

To elucidate more on the formal setting, let us start detailing the negotiation process. If the parties decide to continue the collaboration, the surplus is shared over the outside options of the parties reflecting their *bargaining power*. And the collaboration is continued only if the *quasi-rents*, the difference between the surplus and the *aggregate outside option*, are positive. All these elements are endogenously determined by the initial governance choice. Apart from the standard role of ownership, where a party with more ownership rights obtains a larger outside option, we depart from PR economics in two ways.

First, instead of treating the bargaining power as exogenous or assuming that the parties share equally the surplus over the outside options, we assume that the bargaining power of a party is variable. In the extreme cases one of the parties could be endowed with full bargaining power. For example, it could be given a single control right: the right to make a take-it-or-leave offer, thus capturing all the quasi rents. But we also allow for the intermediate cases when the share of the quasi-rents captured is positive but less than one and proportional to the share of control rights collected.

We advance the idea that by giving a larger control to the unit the company let it take decisions that make itself more fundamental to the collaboration. The company can then use control to endow the unit with a larger bargaining power starting from a situation when it has none. Hence, it can commit to reward the unit with a share of the surplus to be obtained when negotiating. In doing so we depart from the typical assumption in many contexts that the initial bargaining positions of the contracting parties explains the allocation of control. We look instead at the opposite direction of causality, from control to bargaining power.

Second, we relax the standard assumption that the parties always prefer to continue the collaboration and share the surplus, with the outside options serving only as out of the equilibrium threat points. We distinguish between collaborations that are *stable*, when break up never happens, and collaboration that are *unstable*. We shall see that the management of stable and unstable collaborations entails quite different governance choices.

Having set the link between ownership, control and the negotiation outcome, we address the optimal design of the governance ex ante building on agency theory. As we said, we study

a large company managing a collaboration with a small research firm. Besides the difference in the dimension between the parties, we also consider the case when the research unit is cash constrained. We can then make the reasonable assumption that the large company initially has a strong bargaining position and acts as the principal having all the bargaining power. The contractual governance is determined then by the company's take-it-or-leave offer to the unit.

According to the description of the negotiation given above, by allocating bundles of ownership and control rights the company can put the unit in a better bargaining position starting from a situation where it has none. And this must be done providing the unit with the optimal incentives to invest in research. Below we discuss some of our findings using a numerical example.

A numerical example and main results. Let's say that there are four distinct research outputs and that the ownership pattern is fully specified by allocating four distinct IPRs. If we let ϕ be the fraction of IPRs collected by the company, then $\phi \in \left\{0, \frac{1}{4}, \frac{2}{4}, \frac{3}{4}, 1\right\}$. The unit exerts a certain research effort $a \geq 0$, which together with the ownership pattern determine the outside options of the parties when negotiating as well as the surplus from continuation. The surplus, say in M\$, is uncertain and can take a value $a \cdot 3$, $a \cdot 2$, or $a \cdot \underline{k}$ with the same probability, where $\underline{k} > 0$. For the purpose of our example we also need to specify the aggregate outside option, also expressed in M\$, that we define $aB(\phi)$. Assume that $B(\phi) = 1$, 1.25, 1.20, 1.10, 1 when $\phi = 0, \frac{1}{4}, \frac{2}{4}, \frac{3}{4}, 1$, respectively. Note that B reaches its maximum at $\phi = \frac{1}{4}$, with $B(\frac{1}{4}) = 1.25$, while its minimum value is 1. We shall see that

these numbers are in line with our model.

The company initially has all the bargaining power and designs the contract. Let's assume that it is not possible to contract on the research effort, only the allocation of IPRs can be specified. The main theoretical prescription from PR economics[2] is that the company collects all the IPRs, even if it would be preferable to give (part of) them to unit, since it has no money to compensate the company. And since the unit has no bargaining power in the negotiation either, it has no incentive to exert an effort and $a = 0$.

Let's allow now for the possibility that the initial contract can design the configuration of control. The company can vary the fraction λ of control rights he keeps for itself, while allocating a fraction $1 - \lambda$ to the unit and thereby giving up a share $1 - \lambda$ of the surplus in the negotiation. How should the company allocate control, and how should it be combined with ownership to design the governance? We must distinguish different cases, the crucial aspect being whether the company must manage a stable or an unstable collaboration.

Let's consider first the case of a stable collaboration. This is the case when the quasi-rents are always positive, or when the surplus in the worst case scenario, $a \cdot \underline{k}$, is not lower than the maximum aggregate outside option, $a \cdot 1,25$. The parties will always prefer to negotiate over the allocation of the surplus. The prescription of our model is that the company collects ownership rights, $\phi = 1$. But differently from standard PR economics, our model further specifies that the company must allocate to the unit the majority of control rights. For example, assuming that $a \cdot \underline{k} > a \cdot 1,25$ and that the expected value of the surplus is $a \cdot 2.5$,

[2] Here we make reference to the results by Aghion and Tirole's (1994) model on the management of innovation. We discuss this model in further detail later on.

our model predicts that the unit gets about 83% of the control rights, or $\lambda \simeq 0,17$.

The scenario above arises whenever the surplus is expected to be quite large. Interestingly, if the surplus is expected to be low the governance choice of a stable collaboration changes. Still in the case when $a \cdot \underline{k} > a \cdot 1,25$, assume that the expected value of the surplus is $a \cdot 1.5$. The company must now collect the control rights, $\lambda = 1$, thus capturing all the quasi-rents in the negotiation. For example the initial contract can specify that the company has the right to make a take-it-or-leave offer to the unit when negotiating. But at the same time it must allocate to the unit most of the IPRs, or $\phi = \frac{1}{4}$.

So far our model predicts that the company must either collect ownership and allocate bundles of control rights, or collect the control rights and allocate to the unit part of the IPRs. But in reality we observe that ownership and control rights exhibit a much larger variability as both of them can be allocated to the research unit. Can our model accommodate for this? Interestingly, we show that when allowing for break up the company must allocate to the unit bundles of both ownership and control rights, choosing the right mix of the two.

Let's consider this last case. To allow for break up, in the same example as before just set $\underline{k} = 1.1$ while assuming that the expected value remains $a \cdot 2.5$. The ownership pattern now influences the probability of continuation. The company could avoid break up by simply collecting the ownership rights, setting $\phi = 1$. Thus, since $a \cdot 1.1 - a \cdot 1 > 0$, the quasi-surplus are always positive. But is it really optimal to avoid break up? There is also the possibility that the company renounces to make the collaboration stable and allocates to the unit some IPRs. If for example it retains one IPR, so that $\phi = \frac{1}{4}$ and $B(\frac{1}{4}) = 1,25$, we observe break

up when the surplus is $a \cdot 1.1$, which happens in $\frac{1}{3}$ of the cases. And our model predicts that the unit only gets about 35% of the control rights, $\lambda \simeq 0,65$.

But why should such a choice be the optimal one? It seems controintuitive that the company should increase the unit's outside option when the collaboration may be interrupted. The reason why this happens is that when the unit collects some IPRs it expects a larger payoff from the negotiation, and hence has a larger incentive to invest ex-ante. We shall see that to provide the optimal incentives the company must indeed allocate ownership as to maximize the aggregate outside option, thus maximizing the probability of break up.

Structure of the paper. We set up a framework that incorporates the main aspects illustrated in our discussion and replicates the simple numerical example above. The formal model provides some deeper insight in the management of research collaborations highlighting the role of the contractual governance. We make three contributions.

First, by comparing the cases when the unit's research effort is contractible and when it is not, we show how the limits to contracting affects the governance choice. This is because in the latter case the company must provide to the unit the right incentives to invest in addition to convince it to start collaborating. Second, we show that the problem of managing a collaboration, and the relative governance design, are very different according to whether the collaboration is stable or unstable. We highlight a new role for ownership in the latter case that has not been analyzed in the literature and show that it is never in the company's interest to try to stabilize a collaboration. Our third contribute relates to a few suggestions for the empirical analysis of contracts. We discuss the testable hypotheses

of our framework in further details after having presented our main results.

From the theoretical point of view, we also shed a new light on the well known problems of governing a transaction by incomplete contracts. The general message of our analysis is that the governance tends to become more complex as we move from a setting of contractible effort and stable collaborations to a setting where the research effort cannot be contracted and the collaboration is unstable. The paper is organized as follow. In section 2 we briefly discuss the empirical and theoretical literature. In section 3 we set up the formal model. In section 4 and 5 we study how to manage a stable and an unstable collaboration. In section 6 we comment on our main results and section 7 concludes.

2 Literature review

We very briefly review different streams of literature by only mentioning those works that come close to our framework or whose insights have been used for our modelling choices.

2.1 Theoretical literature

The property-rights view advanced by Grossman and Hart (1986) and Hart and Moore (1990) is the starting point for studying the role of ownership in affecting the decisions of economic agents. When only incomplete contracts can be used to govern a relationship, the main prescription of PR economics is that ownership should be given to the party whose investment has the larger marginal effect over the final outcome. And the key idea is that ownership can protect the parties by granting to them a larger negotiation payoff ex post, thereby providing the incentives to invest ex ante.

Aghion and Tirole (1994) rely on a PR framework to investigate the management of innovation. They explore the relationship between a company and a research unit when the terms of the contract specify the allocation of the property right on any forthcoming innovation. They also make the additional point that an inefficient allocation of ownership may arise when the unit is financially constrained. The company could transfer ownership to the unit if this is optimal, but this requires a compensation that the cash constrained unit cannot afford, hence the inefficiency.

PR models provide important insights in how to manage relationships. But as it stands the general framework does not capture the main features of the contractual environment in research collaborations as discussed in section 1. Many times the problem is not whether to integrate or not with the other party, or else to form a joint venture, the typical decision analyzed in PR economics. The challenge is to create and manage new forms of flexible organizations and the design choices go beyond the allocation of property rights and involve control rights.

In PR economics ownership and control coincide as "the possession of residual control rights is taken virtually to be the definition of ownership." (Hart, 1995). Thus, the incompleteness of contracts is modelled assuming that only *residual control rights* can be transferred by changing the underlying ownership pattern. Nevertheless, it is actually possible to think that the parties in a relationship restrict or enlarge the residual control rights granted to the asset owner by means of certain *specified control rights*, or rights that are formally specified in the contract separately from the ownership.

While commonly used in practice, such contractual environment has not been analyzed extensively in the literature. Besides the theoretical relevance of allowing for a separation of ownership and control, such an extension can help to capture actual contractual environments in a greater detail and gain a better understanding of observed arrangements. But what is the role of control rights exactly, and how do they differ from ownership rights?

We argue that a party with larger control can increase its bargaining power. In advancing this argument we build on the literature in rent-seeking. For example, rent-seeking give rise to influence activities (Milgrom, 1988). This can also be used to create a form of deferred compensation (Rotemberg, 1994). Rajan and Zingales (1998) look at power-seeking activities. In the same vein of incomplete contracts, they focus on the *access* to resources rather than ownership. A privileged access confers the opportunity to specialize to the resources, gaining more power in the negotiation.

We address the role of control focusing on those contractual obligations which are conceptually separated by ownership. By linking control to bargaining power, we address the endogenous formation of the configuration of control.

2.2 Managerial and sociological literature

In postulating the link between control over resources and bargaining power we also build on the sociological literature. As suggested by the resource dependence theory (Emerson, 1962) the outcomes from an exchange relationship are a function of the dependence of one of the parties to this relationship on the other party to obtain needed resources. Pfeffer and Salancik (1978) also suggest that the control over critical resources constitutes power in

inter-organizational relations. A party that contributes more to the decision process will be more powerful than the other party.

The twist in our analysis is that we link the incentives of the parties to escape dependence and their ability to alter the relative bargaining power to the allocation of control over resources. Instead of addressing how the bargaining power of the parties affects the distribution of control in the collaboration, we take the opposite direction of causality assuming that one party, the company, initially has all the bargaining power but can decide to endow the other party, the unit, with some power by allocating properly shares of control rights.

Also in the managerial literature there is a renewed interest in the determinants of bargaining power, with a special attention to the resource-based view (see Coff, 1999). Bowman and Swart (2007) is the only example we are aware of illustrating how control can be related to bargaining power. They illustrate the bargaining relationship between the owner of *separable* physical capital and the owner of non-physical *embodied* capital referring to the control over the deployment of *embedded* capital forms. The usual divergence of interests between the parties takes a particular form as embedded capital may be changing subject to efforts to push it toward either separable capital or embodied human capital, thereby altering the relative bargaining positions of the parties.

Finally, the link between control and bargaining power has also been explored more recently by Panico (2010). But he provides a different incentive-based view of the problem as it considers the case of hidden information. He builds up an adverse selection model where only control rights can be allocated, while ownership is given.

2.3 Empirical literature

In many contexts governance structures have become more flexible, using contractual forms to go beyond ownership patterns. Baker et al. (2008) offer evidence on the importance of *contractual bridges* linking firms in what they call strategic alliances. They stress the contractual movements of decision rights and payoffs across firm boundaries and propose a model to analyze a wide range of governance structures. Elfenbein and Lerner (2003) stress the augmented importance of specified control rights as opposed to ownership rights and highlight that:

> "Specified control rights place boundaries on the set of decisions that contracting parties can make and thus serve a role similar to ownership in the property-rights approach in creating incentives. Empirical analyses of contracting should, therefore, analyze the allocation of specified control rights in addition to ownership."

As for research collaborations, contractual forms of collaborations have become increasingly more common over the last decades. Hagedoorn (2002) and Narula and Hagedoorn (1999) show that this is specially true in the pharmaceutical and the information technology industry. Going into the details of contracts, Lerner and Merges investigate the role of control rights examining their allocation in alliances between small biotech and large pharmaceutical firms. In their sample of 200 alliances they find evidence that the control rights to the parties in every stage of the project are carefully delineated:

> "Actual alliances assign a wide variety of control rights, and control rights

> over various aspects of the alliance are assigned in different ways...Practitioners suggest that no single control right stands out as critical. Rather it is the accumulation of rights to control contingencies that makes an alliance particularly favorable to the R&D or the financing firm."

Control allocation in R&D collaborations is critical as the firms may have a diverging interest regarding the use of the resources of the project. For example, Lerner and Malmendier (2010) argue that a typical problem is that the R&D firms realize "project substitution"or "project cross-subsidization"when using the resources of the project. They argue that the partners endogenously generate rights to govern their relationship, and that for example the company firms respond to this problem by obtaining the unconditional right to terminate the research agreement.

The augmented importance of control rights does not diminishes the importance of ownership. Hagedoorn and Hesen (2007) highlights that in research collaborations it is very important for the partners to allocate the rights to the research outcomes. Often ownership and use of the results are defined through the grant of an intellectual property right to one of the parties and a license to the other party. Regarding this last point, Arora and Merges (2004) highlight how patents are used to structure collaborations between independent firms. Besides ownership over assets required for production and commercialization, patents can limit the ability of one partner to act opportunistically after the other has specialized his technology.

In the light of this empirical evidence and the discussion of the theoretical papers, to dig into the working of research collaborations we have to go beyond the common PR wisdom to provide a more refined microlevel analysis of the contractual governance of research. A framework is needed to account for the allocation of both ownership and control by means of contracts as well as for the possibility that these rights are shared between the contracting parties. Below we build a simple model that goes in this direction.

3 Model set-up

We investigate the collaboration between a large company, C, and a small research unit, R. Both parties are risk neutral and R is cash constrained. The collaboration unfolds along three stages (see also Figure 1 below): i) contracting at $t = 0$, when the governance choice is made; ii) research at $t = 1$, when R exerts an effort $a \geq 0$ and a technological shock realizes, and iii) negotiation at $t = 2$, when the parties decide whether to share the continuation surplus or to break up.

Sequence of events. When the collaboration starts C acts as the principal having all the bargaining power. Therefore, the governance is set by a take-it-or-leave offer that specifies the fraction of ownership rights ϕ $(1-\phi)$ and of control rights λ $(1-\lambda)$ allocated to C (to R).[3] The initial contract also establishes the payment $p \geq 0$ from C to R and possibly the research effort a.

Remark 1 The asymmetry in the bargaining power is a standard assumption in agency theory and in our setting it has two justifications. First, it captures both the asymmetry in

[3] For modelling purposes both rights are assumed to be a continuum.

the relative dimension between firms and the fact that there can be many cash constrained research units seeking financial resources to conduct research. Second, since we investigate the use of control to grant some bargaining power in the negotiation, it is useful to consider the case when R initially has no power and hence cannot influence the contract. As we said, we reverse a common reasoning according to which the initial bargaining positions of the parties in a relationship determine the allocation of control and the features of the contract. This is certainly reasonable if two firms having symmetric positions collaborate, which is exactly the opposite of the real situation we want to study.

At $t = 1$ there is the research stage when R exerts a research effort a and a technological shock realizes. At $t = 2$, the parties negotiate having learned the value of the continuation surplus $x(\cdot)$ and their outside options, $V(\cdot) > 0$ for C and $v(\cdot) > 0$ for R. If they negotiate over the allocation of $x(\cdot)$ the parties obtain negotiation payoffs in excess of their outside options corresponding to the generalized Nash-Bargaining solution.[4] Below we elucidate more on the role and the determinants of x, V, v in the negotiation.

Payoffs and main definitions. R can refuse C's initial offer, in which case the collaboration does not start and both parties obtain a reservation payoff of zero. Otherwise R initiates research and incurs a disutility from effort $\frac{1}{2}a^2$, that can also be thought as the opportunity cost from giving up other activities. The surplus $x(\cdot)$ depends on a technological shock captured in a random variable k. We assume that $x(\cdot) = ak$, where k distributes uniformly over a support $[\underline{k}, \bar{k}]$, $\underline{k} > 0$, and $E(k) = \hat{k}$.[5] The outside options of the parties are also increasing in a as well as on the fraction of ownership rights, which is the standard

[4] See remark 2 for more details.

[5] We could also work with a more general setting where k has a cdf $F(k)$. We did this in a previous version of the paper. Such an extension complicates the analysis but does not add much in terms of economic intuition.

assumption in PR economics. We simplify assuming that[6]

$$V(\cdot) = a\sqrt{\phi}$$

and

$$v(\cdot) = a(1-\phi).$$

It is also useful to introduce the definition of aggregate outside option,

$$aB(\phi) = a[\sqrt{\phi} + (1-\phi)],$$

of quasi-rents,

$$aq(k,\phi) = a[k - B(\phi)],$$

and expected quasi-rents,

$$aQ(\phi) = aE[q(k,\phi)] = a[\hat{k} - B(\phi)].$$

We start investigating the management of a stable collaborations, maintaining the standard assumption that break up cannot happen. As in the numerical example in section 2, it is easy to provide a condition related to the quasi-rents. Noting that B reaches its maximum at $\phi = \phi^* = \frac{1}{4}$, and $B(\frac{1}{4}) = \frac{5}{4}$, the collaboration is stable if $\underline{k} \geq \frac{5}{4}$. In such a case the ownership pattern only matters for the allocation of the surplus through the effects over the outside options. As in PR economics we assume that ownership does not affect the relative bargaining power of the parties. Our point of departure is to assume that control matters

[6] This assumption is introduced only to work with a closed form solution. It is not crucial and what really matters is that the functions V and v are increasing in the share of ownership rights, and concave.

for who capture which share of the surplus, that we assume to coincide with the fraction of control.

Remark 2 The assumption that control coincides with the bargaining power is not crucial, we could work with a more general setting when the bargaining power is $\alpha = f(\lambda)$, where f is a function increasing in λ. And our assumption can be justified as in the following examples. First, think of control the right to make a take-it-or-leave-offer to the other party when negotiating, with $\lambda \in \{0, 1\}$. If $\lambda = 1$, C makes the offer to R and provides it with its outside option $v = a(1-\phi)$ while keeping the difference $a[k-(1-\phi)]$. If instead $\lambda = 0$, R makes the offer to C giving to it $V = a\sqrt{\phi}$ and keeping the difference $a[k-\sqrt{\phi}]$.

More generally, we can interpret $\lambda \in [0, 1]$ as a probability, the portion of cases when C is entitled with the right to make the offer to R. To a larger λ corresponds a larger control of C over the collaboration and its expected negotiation payoff (for a given k and ϕ) is

$$\begin{aligned} & \lambda a[k-(1-\phi)] + (1-\lambda)a\sqrt{\phi} \qquad (1) \\ = \; & a\sqrt{\phi} + \lambda a q(k,\phi). \end{aligned}$$

Equivalently, R's negotiation payoff is

$$a(1-\phi) + (1-\lambda)aq(k,\phi). \qquad (2)$$

Note that (1) and (2) correspond to the generalized Nash-bargaining solution. Saying larger control is like saying larger bargaining power.

A second interpretation is that larger control allows for more rent-seeking, as discussed in section 2. If we think of control over the decisions when conducting research, over assets, etc., larger control means a larger ability to obtain an increase in the bargaining power. To the extent that they involve costly time and effort, rent-seeking can be wasteful as it does not increase the surplus. In our analysis we put these inefficiencies aside and assume that the configuration of control only influences the allocation of the surplus, but not its level, which is the interpretation behind (1) and (2).

Having clarified the basic role of ownership and control, let's discuss now the governance choice for an unstable collaboration. The condition to observe break up derives from imposing that the quasi-rents are negative for some realization of the technological shock k. Noting that the function $B(\phi)$ at its minimum is equal to 1, $\underline{k} < 1$ is a necessary condition for the collaboration to be unstable. In such a case the ownership pattern also influences

the probability of break up, which for a given ϕ is

$$\Pr[q(k,\phi) \leq 0] = \Pr[k \leq B(\phi)] = \frac{B(\phi) - \underline{k}}{\bar{k} - \underline{k}},$$

where we have used the fact that k distributes uniformly.

Remark 3 We shall see later on how the expected negotiation payoffs change passing from a stable to an unstable collaboration. Here we comment on a different aspect. While $\underline{k} < \frac{5}{4}$ is a necessary condition to observe break up, it could not be sufficient. We have seen this in the numerical example. If $1 < \underline{k} < B(\phi^*) = \frac{5}{4} < \bar{k}$, in principle C could choose an ownership allocation such that the surplus is always positive, for example setting $\phi = 1$, in which case $B(1) = 1 < \underline{k}$. But we shall see that this is never an optimal choice, implying that $\underline{k} < \frac{5}{4}$ is a necessary and sufficient condition for a collaboration to be unstable. This is proved formally in proposition 3.

Contractibility assumptions. The parties can contract on p, ϕ and λ. As for the research effort a, C does observe it but we distinguish between the case when it is verifiable by a third party, and hence contractible, or not. In the first case it is possible to specify R's research effort in the initial contract and there is no incentive issue. In the second case instead C must provide R with the incentives to exert a nonverifiable effort. This additional constraint explains why the difference in the governance choice.

The forms of governance. We distinguish four forms of governance. The first one is the reference point when C collects both ownership and control rights, $\phi = \lambda = 1$. In the *ownership based governance*, C shares ownership with R, transferring to it a portion $1 - \phi$, while collecting the control rights, $\lambda = 1$. In the *control based governance*, control is shared with R, that keeps a portion $1 - \lambda$, but C collects the ownership rights, $\phi = 1$. Finally, with a *mixed governance* C allocates to R a portion of ownership and of control rights.

We make the assumption that whenever two forms of governance allow for the same expected payoff, C chooses the one that economizes on the allocation of rights. Thus, C prefers to collect ownership and control rights as opposed to allocating them to R if this does not change its expected payoff, and under the same conditions it prefers an ownership or a control based governance to a mixed one. This simply reflects the fact that there can be costs of contracting that are larger the more complex the governance to be specified in the initial contract.

Figure 1 below describes the timing and the main aspects of the research collaboration.

*Figure*1

Having illustrated the main ingredients of the model we can now start analyzing the optimal governance choice under different circumstances. In section 4 and 5 below we study how the governance choice relates to: i) whether C can observe R's research effort or not, and ii) whether the collaboration is stable or unstable.

4 Managing a *stable* collaboration

We start considering how to manage a stable collaboration, when $\underline{k} \geq B(\phi^*) = \frac{5}{4}$, and study how the governance choice depends on the contractibility assumption over a.

4.1 The case of a *verifiable* research effort

As a preliminary result, we consider the benchmark when a is verifiable and hence contractible. We can prove the following straightforward proposition.

Proposition 1 *To manage a* stable *collaboration when the research effort is* verifiable *C must collect both ownership and control rights, $\phi = \lambda = 1$. R exerts an effort $a = \hat{k}$, it is provided with a payment $p = \frac{\hat{k}^2}{2}$ and is left at its zero reservation utility, while C obtains an expected payoff of $\frac{\hat{k}^2}{2}$.*

According to proposition 1, absent any incentive issue there is no point in allocating ownership or control rights to the research unit and the company must only provide an adequate up-front payment. Such result might seem hardly surprising given that we are in a first-best world. But we shall see that it does not hold when the collaboration is unstable (proposition 3). Before providing this result we address the governance choice when the effort is nonverifiable.

4.2 The case of a *nonverifiable* research effort

Consider now the case when R' research effort cannot be verified and specified in the initial contract. C can only *induce* R to exert a certain effort by choosing accordingly a governance form. We can prove the following.

Proposition 2 *To manage a* stable *collaboration when the research effort is* nonverifiable *C must choose:*

i) an ownership based *governance with a share $\tilde{\phi} = 1 - \frac{\hat{k}}{2}$, if $\hat{k} \leq 2$;*

ii) a control based *governance, with a share $\tilde{\lambda} = \frac{1}{2} - \frac{1}{2}\frac{1}{\hat{k}-1}$, if $\hat{k} > 2$.*

In both cases R exerts an effort $a = \frac{\hat{k}}{2}$, it is provided with the lowest payment, $p = 0$, and obtains an expected payoff $\frac{1}{8}\hat{k}^2$, while C obtains an expected payoff $\frac{\hat{k}^2}{4}$.

Proposition 2 provides us with different information. First, differently from proposition 1 where an up-front payment is enough to engage the unit into the collaboration, C must now reward R by setting optimally the payoff it can obtain when negotiating. In this way the

unit's returns from the collaboration depends on its research effort. Interestingly, the choice between an ownership and a control based governance depends on the parties' expectation about the surplus from collaborating.

If the surplus is expected to be large, $\hat{k} > 2$, then the company must collect the ownership rights and transfer to the research unit a share $\tilde{\lambda}$ of control rights. And control tends to be more concentrated the more profitable the collaboration is expected to be. If instead the expected surplus from collaborating is quite low, $\hat{k} \leq 2$, then the company must change the governance and collect the control rights, while transferring to the research unit a fraction $\tilde{\phi}$ of ownership rights. And in this case ownership tends to be more concentrated the less profitable the collaboration is expected to be.

We have therefore reached the conclusion that in the extreme cases of very low or very high expectations over the surplus, the governance choice with a nonverifiable and a verifiable effort tend to resemble each other, while the differences between the two cases are mostly evident for intermediate values of $\hat{k}$. Nevertheless, note that the payment is always set to the minimum level, $p = 0$, and that we observe an underprovision of effort as $a = \frac{1}{2}\hat{k}$ when it is nonverifiable, instead of $\hat{k}$. Moreover, there is a redistribution of payoffs since the unit obtains a positive rent $\frac{\hat{k}^2}{8}$, as compared to zero, and C obtains $\frac{\hat{k}^2}{4}$, as compared to $\frac{1}{2}\hat{k}^2$. This implies that because of the noncontractibility of effort there is a deadweight loss of $\frac{\hat{k}^2}{8}$.

The results obtained up to now for the management of a stable collaboration integrate the insights on the allocation of ownership and control from a PR economics perspective within familiar results in agency theory. In section 5 below we address our second point of

departure from PR economics allowing for the possibility of break up.

5 Managing an *unstable* collaboration

Break up can happen when the quasi-rents are negative for some realization of the technological shock k, or $\underline{k} < \frac{5}{4}$. We have seen that there two cases to be considered. If $1 < \underline{k} < \frac{5}{4} < \bar{k}$, in principle C could stabilize the collaboration, setting for example $\phi = 1$, in which case $B(1) = 1 < \underline{k}$. If instead $\underline{k} \leq 1 < \frac{5}{4} < \bar{k}$, break up can always happen and C can only affect the probability of such an event.[7] Below we formally prove that it is never optimal to choose ownership to stabilize the collaboration even if this is a feasible choice, and that therefore $\underline{k} < \frac{5}{4}$ is really a necessary and sufficient condition for the collaboration to be unstable.

5.1 The case of a *verifiable* research effort

We first show that even in a first-best world the ownership pattern must be properly designed to account for the probability of break up. We rely on the following lemma.

Lemma 1 *When contracting at $t = 0$, the expectation over the quasi rents, provided that they are positive, is $\Gamma(B(\phi)) = \frac{(\bar{k}-B(\phi))^2}{2(\bar{k}-\underline{k})}$, and the expectation over the aggregate payoff from the negotiation is $\Phi(B(\phi)) = B(\phi) + \Gamma(B(\phi))$.*

Equipped with lemma 1 we can now prove the following result.

Proposition 3 *Even if feasible, it is never optimal to stabilize a collaboration. To manage an* unstable *collaboration when the research effort is* verifiable *C must choose an ownership based governance where $\phi = \phi^* = \frac{1}{4}$. R exerts an effort $a = \Phi(\frac{5}{4})$ and is left at its zero reservation utility, while C obtains an expected payoff $\frac{1}{2}\left(\Phi(\frac{5}{4})\right)^2$.*

[7] There is also the third case when the probability of break up is one, or $\bar{k} < 1$. But this case is not interesting as there is no role for the allocation of control.

Allowing for break up changes the governance choice even when the effort is contractible. Particularly, it is never in the company's interest to try to stabilize a collaboration when this is possible. On the contrary, ownership is allocated as to maximize the aggregate outside option, $B(\phi)$ and therefore to maximize the probability of break-up. This is because to increase the expected surplus by increasing a the company must increase the probability of break-up. Note the difference with proposition 1, when the company had to collects both ownership and control rights.

5.2 The case of a *nonverifiable* research effort

We now study how to manage an unstable collaboration when a cannot be specified in the initial contract. This is the only case when a mixed governance does strictly better, as showed in the proposition below.

Proposition 4 *Even if feasible, it is never optimal to stabilize a collaboration. To manage an* unstable *collaboration when the research effort is* nonverifiable *C must choose a mixed governance where $\phi = \phi^* = \frac{1}{4}$ and $\lambda = \frac{1}{2} + \frac{1}{8}\frac{1}{\Gamma(\frac{5}{4})}$. R exerts an effort $a = \frac{1}{2}\Phi(\frac{5}{4})$, it is provided with the lowest payment, $p = 0$, and obtains an expected payoff $\frac{1}{8}[\Phi(\frac{1}{4})]^2$, while C obtains an expected payoff $\frac{1}{4}[\Phi(\frac{1}{4})]^2$.*

We have proved that when admitting for the possibility of break-up the governance is mixed and both ownership and control must carefully allocated. The ownership pattern coincides with the benchmark when a is contractible, implying that the probability of break-up does not change because of the more challenging contracting environment. What changes is that now the unit is not rewarded with an initial payment, it only receives a share of the surplus in case of continuation. Note also that ownership and control combine to induce a

lower research effort and a redistribution of payoffs from the company to the unit. Similarly to proposition 2, because of the nonverifiability of effort there is a deadweight loss of $\frac{1}{8}[\Phi(\frac{1}{4})]^2$.

6 Discussion

Our analysis highlights how the limits to contract affect the governance design problem in a setting where a company contracts with a small research unit. We observe that a mixed governance is needed only in challenging environments when both nonverifiability and break up concerns are in place (Proposition 4). If one of these two features is missing, then it suffices to allocate only ownership and control rights (Proposition 2 and 3). In the ideal case where the effort is contractible and the collaboration is stable the company collects both ownership and control rights (Proposition 1).

There are two aspects that we want to emphasize. First, the management of a stable collaboration depends sensibly on the expected value of the surplus. As we have seen in proposition 2, the company must choose an ownership based governance whenever $\hat{k} \leq 2$, otherwise it must rely on a control based governance. Our propositions justify the values of ϕ and λ in the numerical example in section 2. Assume for example that $[\underline{k}, \bar{k}] = [2, 3]$, with $\hat{k} = 2.5$. By point ii) of proposition 2, the company collects the ownership rights, $\phi = 1$, but allocates to the unit the majority of control rights

$$\tilde{\lambda} = \frac{1}{2} - \frac{1}{2}\left(\frac{1}{2.5 - 1}\right) \simeq 0,17.$$

Assume now that the collaboration is stable but that $[\underline{k}, \bar{k}] = [1.25, 1.75]$, with $\hat{k} = 1.5$. Just because of the lower expected surplus a quite different governance is required. By point i) of

proposition 2, the company must collect the control rights, $\lambda = 1$, having just to specify in the contract that it has the right to make a take-it-or-leave offer to the unit when negotiating. But at the same time it must allocate to the unity 75% of the ownership rights, as

$$\tilde{\phi} = \frac{1}{2} - \frac{1.5}{2} = \frac{1}{4}.$$

The second aspect relates to the fact that managing stable and unstable collaborations also entails very different governance choices. To go back to the numerical example, consider the case when $[\underline{k}, \bar{k}] = [1.1, 3.9]$. We still have that $\hat{k} = 2.5$, but now there could be break up. We have seen that the company could avoid this by simply collecting the ownership rights. But proposition 4 tells us that this is never an optimal choice. On the contrary, ownership must be allocated as to maximize the probability of break up, thus setting $\phi = \phi^* = \frac{1}{4}$. But at the same time the company must collect the majority of control rights. By lemma 1,

$$\Gamma(\frac{5}{4}) = \frac{(3.9 - 1.25)^2}{2(3.9 - 1.1)} \simeq 1.25$$

while by proposition 4

$$\lambda = \frac{1}{2} + \frac{1}{8}\frac{1}{\Gamma(\frac{5}{4})} \simeq 0,60.$$

Note that this last case is intermediate between the first two regarding the allocation of ownership and control.

7 Conclusions

We propose a simple and tractable framework that integrates agency theory with the PR economics to investigate the collaboration between a company and a small research unit. The

company makes an initial offer to the unit but differently from the standard agency model the parties negotiate ex-post. The initial contractual arrangement determines the relative bargaining positions of the parties but differently from PR economics, where ownership coincides with control and only residual control rights can be transferred, in our framework the parties' control can be disentangled by ownership referring to specified control rights.

We regard control as variable and to be optimally chosen along a continuum, and advance the idea that the allocation of control affects the relative bargaining power of the parties. A second aspect of our analysis pertains to the distinction between stable and unstable collaborations. This distinction allows us to introduce a new role for the allocation of ownership that goes beyond the effects on the ex ante incentives to invest as the ownership patterns influences the probability of break-up.

There are two possible extensions that we believe might help to deepen our understanding of research collaborations. First, introduce risk-aversion in the analysis and see how optimal risk-sharing considerations influence the governance choice. Second, allow for the case when the company and the unit have asymmetric information about the key aspects of the research process, such as the feasibility of the project, the level of expertise in dealing with it or the payoff it is possible to obtain outside the collaboration. All these aspects complicate the analysis and lead to frameworks that are technically more demanding.

Finally, we have referred our discussion to research collaborations. The recent empirical literature investigating the features of the contractual forms between firms highlight the combined importance of ownership and control in the governance choice. But we believe that

the theoretical framework developed in the current paper could be extended to other settings where it becomes relevant to set an arrangement ex-ante to affect the relative bargaining position in the ex-post negotiation, both in inter-firms and in intra-firm relationships. We leave these aspects for further research.

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Appendix

Proof of proposition 1.

Proof. Consider first the case of an ownership based governance, when ϕ is set optimally but $\lambda = 1$. When negotiating C offers to R its outside option $a(1-\phi)$ and keeps the difference $ak - a(1-\phi)$. Therefore, C maximizes its expected payoff

$$a\hat{k} - a(1-\phi) - p \tag{3}$$

subject to the two constraints

$$p + a(1-\phi) - \frac{1}{2}a^2 \geq 0 \tag{4}$$

and

$$p \geq 0.$$

(4) is the participation constraint ensuring that it is convenient for R to accept C's initial offer. C can leave R at its reservation utility choosing

$$p = \frac{1}{2}a^2 - a(1-\phi). \tag{5}$$

Assume for a moment that p is positive in equilibrium. Substituting (5) in (3), C maximizes

$$a\hat{k} - \frac{1}{2}a^2 \tag{6}$$

setting $a = \hat{k}$, obtaining an expected payoff of $\frac{\hat{k}^2}{2}$ which does not depend on ϕ. The payment is

$$p = \hat{k}(\frac{1}{2}\hat{k} - (1-\phi)). \tag{7}$$

C can freely choose ϕ to make sure that the payment is non negative, which is for example the case when ownership is concentrated, $\phi = 1$.

Consider now the case of a control based governance, when C sets optimally λ but collects the ownership rights, $\phi = 1$. Since $B(1) = 1$, by (1) and (2) C maximizes

$$a + \lambda a(\hat{k} - 1) - p \tag{8}$$

subject to the two constraints

$$p + (1 - \lambda)a(\hat{k} - 1) - \frac{1}{2}a^2 \geq 0. \tag{9}$$

and

$$p \geq 0.$$

C can leave R at its reservation utility setting

$$p = \frac{1}{2}a^2 - (1 - \lambda)a(\hat{k} - 1). \tag{10}$$

Assume for a moment that p is non-negative. Substituting (10) in (8) C obtains the same payoff as in (6), which does not depend on λ. Therefore, $a = \hat{k}$ and by (10)

$$p = \hat{k}[\frac{1}{2}\hat{k} - (1 - \lambda)(\hat{k} - 1)].$$

C has to make sure that the payment is non negative, which is for example the case when control is enough concentrated, so $\lambda = 1$.

Finally, along the same line of reasoning it is easy to show that C cannot do any better when choosing a mixed governance, meaning that C optimally sets $\phi = \lambda = 1$ and $p = \frac{\hat{k}^2}{2}$. ■

Proof of proposition 2.

Proof. Consider first the case of an ownership based governance, when $\lambda = 1$. The proof is in the same vein of proposition 1 but with an additional constraint. Instead of C commanding an effort level, a is chosen optimally by R to maximize the payoff in (4). C then faces the incentive compatibility constraint

$$a = 1 - \phi, \tag{11}$$

according to which the participation constraint (4) becomes

$$p + \frac{1}{2}(1 - \phi)^2 \geq 0, \tag{12}$$

which is always satisfied. Hence, C optimally sets $p = 0$ and substituting (11) in (3) it obtains

$$\left[\hat{k} - 1 + \phi\right](1 - \phi), \tag{13}$$

that is maximized at

$$\phi = \tilde{\phi} = 1 - \frac{\hat{k}}{2}. \tag{14}$$

(14) identifies an interior solution provided that $\hat{k} \leq 2$, in which case by (11) R exerts an effort $a = \frac{\hat{k}}{2}$, and by (12) and (13) R and C obtain expected payoffs $\frac{\hat{k}^2}{8}$ and $\frac{\hat{k}^2}{4}$, respectively. If instead $\hat{k} > 2$, we have a corner solution where $\phi = 0$, C obtains $\hat{k} - 1$ and R gets $\frac{1}{2}$.

Consider now the case of a control based governance, when $\phi = 1$. By (9) the incentive compatibility and the participation constraint are

$$a = (1 - \lambda)(\hat{k} - 1) \tag{15}$$

and

$$p + \frac{1}{2}[(1 - \lambda)(\hat{k} - 1)]^2 \geq 0, \tag{16}$$

where the latter is always non negative. Hence $p = 0$ and substituting (15) in (8) it obtains

$$\left[1 + \lambda(\hat{k} - 1)\right]\left[(1 - \lambda)(\hat{k} - 1)\right] \tag{17}$$

that is maximized when

$$\lambda = \tilde{\lambda} = \frac{1}{2} - \frac{1}{2}\frac{1}{\hat{k} - 1}. \tag{18}$$

(18) identifies an interior solution if $\hat{k} > 2$. Substituting (18) in (15) the equilibrium effort is $a = \frac{\hat{k}}{2}$, and by (16) and (17) R obtains a payoff $\frac{1}{8}\hat{k}^2$ while C obtains $\frac{\hat{k}^2}{4}$. If instead $\hat{k} \leq 2$, we have a corner solution where $\tilde{\lambda} = 0$, C obtains $\hat{k} - 1$ while R gets $\frac{1}{2}$.

By comparing C's payoffs for an ownership and a control based governance, we immediately see that the former is preferred to the latter iff $\hat{k} \leq 2$, and C's payoff is always equal to $\frac{\hat{k}^2}{4}$. ■

Proof of lemma 1.

Proof. Note first that since k distributes uniformly, the probability of break up corresponding to a certain ϕ is

$$\Pr[q(k, B(\phi)) \leq 0] = \Pr[k \leq B(\phi)] = \frac{B(\phi) - \underline{k}}{\bar{k} - \underline{k}}, \tag{19}$$

while with probability $1 - \frac{B(\phi) - \underline{k}}{\bar{k} - \underline{k}} = \frac{\bar{k} - B(\phi)}{\bar{k} - \underline{k}}$ the parties negotiate and share the surplus. Second, the expected value of the quasi-rents, provided they are positive, are

$$\begin{aligned} E[q(k, \phi) \mid q(k, \phi) \geq 0] &= E\left[k - B(\phi) \mid k > B(\phi)\right] \\ &= E\left[k \mid k > B(\phi)\right] - B(\phi) = \frac{B(\phi) + \bar{k}}{2} - B(\phi) = \frac{\bar{k} - B(\phi)}{2}. \end{aligned}$$

The period $t = 0$ expectation of the quasi rents, provided that they are positive, therefore

are

$$\begin{aligned} E\left[E[q(k,\phi) \mid q(k,\phi) \geq 0]\right] &= \Pr[q(k,B(\phi)) \geq 0] E[q(k,\phi) \mid q(k,\phi) \geq 0] \\ &= \left(\frac{\bar{k} - B(\phi)}{\bar{k} - \underline{k}}\right)\left(\frac{\bar{k} - B(\phi)}{2}\right) = \frac{\left(\bar{k} - B(\phi)\right)^2}{2(\bar{k} - \underline{k})} = \Gamma(B(\phi)). \end{aligned}$$

We can now compute the payoffs from negotiation at time $t = 2$ that the parties expect to obtain when contracting at $t = 0$. At $t = 2$ the parties obtain their outside options with a probability $\frac{B(\phi)-\underline{k}}{\bar{k}-\underline{k}}$, while with probability $\frac{\bar{k}-B(\phi)}{\bar{k}-\underline{k}}$ they obtain the continuation payoffs as in (1) and (2). Therefore, C's expectation is

$$a\sqrt{\phi}\left(\frac{B(\phi) - \underline{k}}{\bar{k} - \underline{k}}\right) + a\left(\sqrt{\phi} + \lambda\left(\frac{\bar{k} - B(\phi)}{2}\right)\right)\left(\frac{\bar{k} - B(\phi)}{\bar{k} - \underline{k}}\right)$$
$$= a\sqrt{\phi} + \lambda a\Gamma(B(\phi)).$$

Equivalently, R's expectation is

$$(1 - \phi) + (1 - \lambda)a\Gamma(B(\phi)). \tag{20}$$

Finally, summing up (**??**) and (20), the expected aggregate payoff from the negotiation for an unstable collaboration is

$$a\Phi(B(\phi)) = a\left(B(\phi) + \Gamma(B(\phi))\right). \tag{21}$$

■

Proof of proposition 3.

Proof. Consider the case of a control based governance. Setting $\phi = 1$ in (**??**) and (20), C maximizes

$$a[1 + \lambda\Gamma(1)] - p \tag{22}$$

subject to the constraints

$$p + a(1-\lambda)\Gamma(1) - \frac{1}{2}a^2 \geq 0. \tag{23}$$

and

$$p \geq 0.$$

C can leave R at its reservation utility choosing

$$p = \frac{1}{2}a^2 - a(1-\lambda)\Gamma(1)] \tag{24}$$

Substituting (24) in (22) and using (21), C obtains

$$\begin{aligned} & a(1+\Gamma(1)) - \frac{1}{2}a^2 \qquad (25) \\ = \quad & a\Phi(1) - \frac{1}{2}a^2, \end{aligned}$$

which does not depend on λ. This is also true when allowing for a generic ϕ, with (24) and (25) reducing to

$$p = \frac{1}{2}a^2 - a(1-\lambda)\Gamma(B(\phi))] \tag{26}$$

and

$$a\Phi(B(\phi)) - \frac{1}{2}a^2. \tag{27}$$

Hence C's payoff never depends on the choice of control. Consider then the case of an ownership based governance, when $\lambda = 1$ and ϕ is chosen optimally. C maximizes (27) choosing

$$a = \Phi(B(\phi)) \tag{28}$$

and obtaining a payoff

$$\frac{1}{2}[\Phi(B(\phi))]^2. \tag{29}$$

We now prove that in equilibrium $\phi = \phi^* = \frac{1}{4}$. Note first that

$$\frac{d\Phi(B)}{dB} = \frac{d}{dB}\left(B + \Gamma(B)\right) = \frac{d}{dB}\left(B + \frac{\left[\bar{k} - B\right]^2}{2(\bar{k} - \underline{k})}\right) = 1 - \frac{\bar{k} - B}{\bar{k} - \underline{k}} \tag{30}$$

can be positive or negative according to whether B is larger or lower than $\underline{k}$. There are two cases to analyze, $\underline{k} < B(1) = 1$ and $\underline{k} > B(1) = 1$. In the first case, B is always larger than $\underline{k}$, $\Phi(B)$ is always increasing in B and therefore C optimally sets $\phi = \phi^* = \frac{1}{4}$. By (28) R exerts an effort $\Phi(\frac{5}{4})$ and by (29) C obtains an expected payoff $\frac{1}{2}[\Phi(\frac{5}{4})]^2$.

If instead $\underline{k} > 1$, C could in principle set $B < \underline{k}$, in which case $\Phi(B)$ is decreasing in B and therefore $\phi = 1$ or 0. In this case the quasi-rents are always positive and the collaboration is stabilized. Therefore we are back to the case of a stable collaboration analyzed in proposition 1, where we had that $\phi \simeq 1$. Therefore, $\phi = 1$ and C's expected payoff is $\frac{\hat{k}^2}{2}$. But this can never be an optimal choice since $\Phi(B)$ is always larger than $\hat{k}$. Hence, in equilibrium $\phi = \frac{1}{4}$ and the collaboration is never stabilized.

It only remains to prove that the equilibrium payment is non negative. Substituting the equilibrium values of a and ϕ in (26),

$$\begin{aligned} p &= \frac{1}{2}\Phi(\frac{5}{4})\left(\Gamma(\frac{5}{4}) - \frac{1}{4}\right) \\ &= \frac{1}{2}\Phi(\frac{5}{4})\left(\frac{\left(\bar{k} - \frac{5}{4}\right)^2}{2(\bar{k} - \underline{k})} - \frac{1}{4}\right), \end{aligned}$$

and it can be easily checked that the term in brackets is strictly positive in the relevant range of the parameters. ■

Proof of proposition 4.

Proof. We follow the same steps as in the proof of proposition 2. Consider the case of a mixed governance. The effort is chosen optimally by R to maximize the payoff in (23). The incentive compatibility and the participation constraints are

$$a = 1 - \phi + (1 - \lambda)\Gamma(B(\phi)) \tag{31}$$

and

$$p + a[1 - \phi + (1 - \lambda)\Gamma(B(\phi))] - \frac{1}{2}a^2 \geq 0, \tag{32}$$

where the latter is strictly positive. Therefore C optimally sets $p = 0$ and substituting (31) in (22) it obtains

$$\left[\sqrt{\phi} + \lambda\Gamma(B(\phi))\right][1 - \phi + (1 - \lambda)\Gamma(B(\phi))] \tag{33}$$

that is maximized when

$$\lambda = \frac{1}{2} - \frac{1}{2}\frac{\sqrt{\phi} - (1 - \phi)}{\Gamma(B(\phi))}. \tag{34}$$

substituting (34), (33) reduces to

$$\frac{1}{4}[\Phi(B(\phi))]^2. \tag{35}$$

As proved in proposition 3, C optimally sets $\phi = \frac{1}{4}$ and therefore by (34)

$$\lambda = \frac{1}{2} + \frac{1}{8}\frac{1}{\Gamma(\frac{1}{4})}, \tag{36}$$

by (31) R exerts an effort

$$a = \frac{1}{2}\Phi(\frac{5}{4}) \tag{37}$$

and obtains a payoff

$$\frac{1}{8}[\Phi(\frac{5}{4})]^2, \tag{38}$$

while C obtains a payoff

$$\frac{1}{4}[\Phi(\frac{5}{4})]^2. \tag{39}$$

■