# Technological policy and cooperation in innovation: A look through a formal model

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Abstract

Most of the empirical literature has shown that public support to firm R&D activities stimulates cooperation in innovation. However, there is not a formal model that studies the relationship between technological policy and R&D cooperation. We develop a principal-agent model from which we determine the structure of incentives that the principal –in our case the government responsible for the elaboration of technological policy programs- has to provide to the agents to stimulate R&D cooperation. Our results show that there is a certain level of incentives that foster cooperation in innovation. The main practical-policy implication of this result is that R&D public subsidies can trigger a behavioral change in the organization of firms´ R&D strategies and this will depend on the amount of such funding. The theoretical implication is that a new methodology –principal-agent model- may provide a useful framework for analyzing the effect of technological policy on (cooperation in) innovation.

*Keywords*: R&D public subsidies, Research partnership, innovation policy, principal-agent model.

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## Introduction

Cooperation in innovation has emerged as an important firm strategy to perform R&D activities in OECD countries (Hagedoorn, 2002; OECD, 2002, 2010). At the same time, governments have promoted and supported research partnership in order to (Hagedoorn et al., 2000): a) correct market failures in R&D investment, particularly in the presence of highly non-appropriable research[1]; b) speed up technological innovation aiming at increased international competitiveness and c) increase technological information exchange among firms, universities and public research institutes.[2]

However, public intervention suggests an important question related to the ex-post evaluation of these technological policies in order to know how public support for R&D and R&D partnerships affect firm behavior and innovation performance. The main question is whether outcomes would have been the same without support, and therefore whether this particular type of policy intervention should be maintained. In this sense several empirical studies have analyzed the impact of public R&D programs on research partnership to evaluate if firm participation in these programs increase their number and therefore if public support creates additional cooperation beyond the level that the market would have produced in the absence of such support (what is known in the literature as behavioral additionality).[3] [4] The general

[1] The necessary justification of public support to R&D investments is provided by traditional economic argument of market failure for R&D that reduces the private incentives to conduct R&D leading to a socially suboptimal level of R&D investment. This argument could be extended to public support of R&D collaboration.

[2] Some examples of the specific programs to encourage collaboration are the Engineering Research Associations in Japan, the Advanced Technology Program in the US and the successive Framework Programs on Research and Technological Development in the European Union.

3 In the technological policy evaluation literature additionality in broad sense means that a public R&D program contributes to create additional welfare that would not have been produced otherwise (Buisseret et al., 1995; Davenport et al., 1998). Because welfare effects are difficult to measure, other indicators of additionality are used. These are input, output and behavioral additionality. In the case of R&D programs input additionality refers to the changes in private R&D expenditure triggered by public support. Output additionality refers to changes in patents and new products obtained by a supported firm. Behavioral additionality refers to changes in collaboration or management strategies caused by participating in public R&D programs.

[4] Most of the program evaluation literature has focused on the impact that public support has on private R&D expenditure, on patenting or on other measures of innovation performance, but not on its effects on firm behavior regarding how these activities are organized (Buson and Fernández-Ribas, 2008).

empirical evidence shows that public R&D funding triggers additional cooperation. However, it is interesting to point out some methodological problems that arise in some studies (e.g., Bayona et al., 2003; Fölster, 1995; Miotti and Sachwald, 2003; Mohnen and Hoareau, 2003) related to subsidy endogeneity and the characteristics of R&D programs. The endogeneity problem arises because the participation in public R&D programs and cooperation may be simultaneous determined because there are some omitted factors in the participation program, such as project characteristics, that affect the decision of cooperation and therefore the results are overstated.[5] With respect to the characteristics of R&D programs there are some programs (e.g., EU programs) in which cooperation is a requirement for obtaining funds, so participation in those programs and cooperation are not different choices. Some empirical works (Belderbos et al., 2004; Buson and Fernández-Ribas, 2008) have explicitly addressed those problems showing some divergence in their results. Belderbos et al. (2004) find that the effect of receiving R&D subsidies is not conclusive, as results vary with the empirical strategy used to control for subsidy endogeneity[6] whereas Buson and Fernández-Ribas (2008) shown that national R&D programs have a positive effect on private vertical cooperation and especially on public-private cooperation. Therefore the conclusion is that, although the results show a positive tendency of the effect of R&D subsidies to cooperation in innovation, careful attention must to be paid to the treatment of the endogeneity of R&D subsidies exploring alternatives procedures to address this issue in order to check the robustness of the results.

Within this context our work tries to extend this research path by developing a formal model that incorporates the role of technological policy on firm cooperation. By considering the relationship established between the government –as the responsible for the design of technological policy- and the innovator firms as an agency

[5] In mathematical terms an endogeneity problem arises when some of the independent variables of the regression equation (due to the omission of relevant variables, measurement errors, simultaneity, etc) are correlated with the error term and therefore the OLS estimators are inconsistent.

[6] When using lagged subsidies, they find a positive effect on the likelihood of vertical and public/private
cooperation, but not on horizontal cooperation. However, when restricting the sample to include only firms that are new to cooperation, R&D subsidies are not found to have any effect on vertical or public cooperation, and moreover have a negative effect on horizontal cooperation.

relationship we develop a basic principal-agent model from which we determine the optimal incentives structure that the principal –i.e., the government- must provide to the agent –i.e., the firms- according to the innovation effort supplied to perform the innovation activities. We consider two innovation environments, one in which firms perform their innovation activities individually and that will serve as a benchmark against the situation in which firms act cooperatively in the innovation process. Our results show that there is a level of incentives that foster firm cooperation in innovation because each agent reaches a higher level of utility when cooperation takes place comparing with the situation of non-cooperation. The main practical/political implication of this result is that public R&D subsidies can stimulate firms to engage in cooperation for innovation and that will depend on the amount of such public subsidies. Also we provide the economic rationality of this result. From the theoretical point of view a new methodology based on a formal model for analyzing the effect of technological policy on cooperation in innovation has been addressed which contributes to a better understanding of this phenomenon.

The rest of the paper is structured as follows. Section 2 introduces the basic framework. In section 3 we study the principal´s solutions –i.e., the technological incentives contract- to innovation agents considering two models: a) model 1 in which each agent perform innovation activities individually –non-cooperation model- and b) model 2 in which each agent collaborate with other agent to perform innovation activities –cooperation model. By comparing both solutions we can determine the structure of incentives that can foster cooperation in innovation. Finally, section 4 presents our conclusions.

## 2. The framework

We consider the relationship established between the government and innovation agents through the technological policy to be an agency relationship in which the government, acting as the principal, designs and incentives contract – the technological policy program – offered to the firms, the agent, to stimulate the development of innovation activities. Thereby, said relationship is formalized through a basic principal-agent model, and in an information asymmetry context in reference to the agent´s level of effort and through which the manner of adopting the optimal contracts for the principal when only the “consequences” of the agent´s actions are observable is studied. Mathematically, the optimal contract is such that maximizes the principal´s level of utility.

Formally we assume that the principal or government´s utility function – social utility function – can be expressed as follows:

$$\textbf{(1)} \qquad U(R, W) = B(R) - v(W)$$

Where $B(R)$ represents the gains that the principal/government obtains from the results deriving from the application of the technological policy (e.g., the number of innovations and/or patents which imply a higher technological level for society) and $v(W)$ represents the cost or the disutility associated with the incentives offered by the government to the agents to develop their innovation activities; mathematically, the functions exhibit the following behavior: $B' > 0$, $B'' \leq 0$, $v' > 0$, $v'' \geq 0$.

The utility function of the agent – innovative firms – can be expressed as:

$$\textbf{(2)} \qquad U(W, E) = u(W) - v(E)$$

Where $u(W)$ is the utility derived from the incentives that the government offers the agent and $v(E)$ represents the cost or disutility associated with the innovation effort supplied by the agent; $u' > 0$, $u'' \leq 0$, $v' > 0$ y $v'' \geq 0$.

Formally, we assume that there are various possible levels of results (in our case innovation results) that the principal may expect – in the following section these possible results will be specified when the principal´s solutions are determined – and, on the other hand, identify the possible actions an agent may take such that each action has a determined cost. In this manner, it is generally assumed that the agent can choose between two possible levels of effort, high effort $(E^H)$ and low effort $(E^L)$, and supplying a high effort is much more costly than supplying a lesser effort. It is also assumed that the principal cannot observe the agent´s actions – i.e., his effort supplied – but the results are observable, which is technically referred to as a model with information asymmetry about an agent´s effort. For this assumption to make sense, each action cannot correspond with a determined level of result, given that if this were the case, observing the result would be the same as observing the agent´s actions. Therefore, each of the agent´s actions - high effort $(E^H)$ and low effort $(E^L)$ - corresponds to a determined distribution of probability regarding the level of results – the following section details these distributions of probability.

These models assume that there is a certain level of "reserve utility" ( $\underline{U}$ ) for the agent. This level of utility represents the utility that the agent - in this case the firm - would receive in the next best available alternative. During the process of designing the outline of incentives, the principal will face two types of restrictions. The first refers to participation constraint: if the principal wants the firm to choose a specific option, - generally, it is assumed that the principal prefers for the agent to supply a higher effort rather than a lower effort – the reserve utility should be greater or equal to the difference between the expected utility of undertaking this action and the costs associated to said action. The second restriction is the incentive compatibility constraint: If the principal wants the agents to choose a specific option, - the same effort assumption as in the first restriction is made – the difference between the expected utility and the costs associated with a high effort should be greater or equal to those associated with low effort. In other words, the incentive compatibility restraint implies that the agent should receive a greater level of compensation as his effort increases.

Taking into account these basic features our main purpose is to analyze the incentives structure that the principal/government must give to the agents to foster cooperation in innovation. Methodologically we proceed considering two innovation environments, one in which the agent perform their innovation activities individually (model 1) and that will serve as a benchmarking against the situation in which the innovation process is performed cooperatively by two agents (model 2). Comparing the agent expected utility levels in both situations we determine the structure of incentives that can promote cooperation in innovation.

## 3. Principal´s solutions to innovation agents

### a) Innovation is performed individually (model 1)

In accordance with the commentaries in the previous section, we assume that two possible innovation results can be identified, high results $(R^H)$ and low results $(R^L)$. The frequency with which the high and low results are presented $(R^H, R^L)$ will depend on the innovation effort supplied by the agent $(E)$ - we will assume that the agent can choose between two levels of effort, high effort $(E^H)$ and low effort $(E^L)$ - and other random variables of the environment. Taking into account the previous statement, the following distribution of probabilities is established:

$$\Pr ob[R = R^H \mid E^H] = p^H$$

$$\Pr ob[R = R^H \mid E^L] = p^L$$

$$\Pr ob[R = R^L \mid E^H] = 1 - p^H$$

$$\Pr ob[R = R^L \mid E^L] = 1 - p^L$$

in which $p^H > p^L$.

Contrarily, the different incentive contracts that the principal offers to each agent can be defined as follows:

$$W^H, si\ R = R^H$$

$$W^L, si\ R = R^L$$

Where $W^H$ y $W^L$ represent the high and low levels of incentives, respectively, that the agent obtains in accordance with the result obtained. The incentives offered by the principal increase as the results increase, which would depend on the effort supplied by the agent. Based on these premises, the agent´s expected utility might be determined based on his effort as is illustrated in the following equations:

**(3)** $$EU^A(E = E^H) = p^H W^H + (1 - p^H) W^L - v(E^H)$$

for a high level of effort

**(4)** $$EU^A(E = E^L) = p^L W^H + (1 - p^L) W^L - v(E^L)$$

for a low level of effort

To calculate the optimal contract, the government must resolve the following problem – assuming that the principal prefers for the agent to supply a high level of effort in the development of innovation activities-:

**(5)** $\text{Min}_{[W^H, W^L]} \; p^H v(W^H) + (1 - p^H) v(W^L)$ Such that

**(6)** $p^H W^H + (1 - p^H) W^L - v(E^H) \geq \underline{U}$

**(7)** $p^H W^H + (1 - p^H) W^L - v(E^H) \geq p^L W^H + (1 - p^L) W^L - v(E^L)$

Where equations (6) and (7) reflect the participation constraint and the incentives compatibility constraint, respectively.[7] The participation constraint encompasses the notion that the agent can reject the contract if the expected utility obtained by that program of incentives is not at least equal to the reserve utility. The incentive compatibility constraint reflects that the agent is willing to select the option proposed by the principal $(E = E^H)$ if said option maximizes the objective function, which is, $EU^A(E = E^H) \geq EU^A(E = E^L)$. Additionally, taking into account that this restriction will be greater in the particular case where the effort is null $(E = E^L = 0)$, equation (7) can be rewritten as follows:

**(8)** $(p^H - p^L)(W^H - W^L) \geq v(E^H)$

Denominating as $\mu$ the participation condition multiplier and as $\lambda$ the incentive compatibility constraint, the Lagrangian first-degree conditions are expressed as:

**(9)** $p^H v'(W^H) - p^H \mu - (p^H - p^L)\lambda = 0 \Leftrightarrow v'(W^H) = \mu + \frac{p^H - p^L}{p^H}\lambda$

**(10)** $(1 - p^H) v'(W^L) - (1 - p^H)\mu + (p^H - p^L)\lambda = 0 \;\; \Leftrightarrow \;\; v'(W^L) = \mu - \frac{p^H - p^L}{1 - p^H}\lambda$

[7] A method for solving constrained optimization problems is the Lagrangian multiplier method (Nicholson, 2005).

Where $(W^H)$ $(W^L)$ denote the incentives that the agent expects to obtain through the optimal contract if $(R = R^H)$ and $(R = R^L)$, respectively.

Given that ($1 > p^H > p^L > 0$) and taking into account that the function $v(E)$ will adopt positive values, representing the disutility associated with effort, equation (8) implies that $(W^H > W^L)$. On the other hand, if we take into account that $v(W)$ is increasing function, then $v'(W^H) > v'(W^L)$. Finally, equations (9) and (10) imply in particular that (λ>0) and (μ>0), which signifies that both restrictions are saturated. Consequently, the participation and incentive constraints characterize the optimal contract in equal terms.

Resolving the system composed by equations (6) and (8), it is expounded that the solution to the problem established by the government to design the optimal contract might be defined as follows:

$$\textbf{(11)} \quad W^H = \underline{U} + v\left(E^H\right)\frac{1 - p^L}{p^H - p^L}$$

$$\textbf{(12)} \quad W^L = \underline{U} - v\left(E^H\right)\frac{p^L}{p^H - p^L}$$

Where ($W^H$) y ($W^L$) represent the optimal incentives a principal must offer the innovative agents in situations of high and low effort respectively. Based on these results, it is verified that the agent´s expected utility, in a hypothetic situation of high effort, considering the incentives established by the principal and equation 2, is equal to the reserve utility – the participation constraint is met.

$$EU^A(E = E^H) = p^H \overline{W}^H + (1 - p^H)\overline{W}^L - v\left(E^H\right) = \underline{U} + v\left(E^H\right) - v\left(E^H\right) = \underline{U}$$

Additionally, it is also verified that in the particular case, where the result obtained in high $(R = R^H)$ and the agent´s effort can be correctly estimated, which is when $p^H$ =1, the incentives received by the agent will cover his reserve utility and will compensate for the disutility associated with the effort level supplied, as well. Surely, the government will offer incentives based on the following expression: $\overline{W}^H = \underline{U} + v\left(E^H\right)$.

**b) Innovation is performed cooperatively (model 2)**

In order to determine the incentive structure that the government should offer the firms so that they decide to cooperate in innovation, the principal´s problem should be resolved taking into account a situation in which the agents cooperate – model in which innovation is performed cooperatively by various agents – so that from here on forward the agent´s expected utility is compared with the agent´s expected utility in model 1. The simplest case of cooperation between two agents will be considered in this model. It should be noted that the innovation´s result will depend on the combined efforts supplied by both agents involved in the project – as in model 1, it is assumed that each of the agents will choose between supplying high effort $(E^H)$ and low effort $(E^L)$. In cases where the agents are cooperating, it will be assumed that three possible innovation results can be identified: high result ( $R^{HH}$ ), low result ( $R^{LL}$ ) and an "intermediate result" ( $R^{HL}$ ), which is inferior to $R^{HH}$ yet superior to $R^{LL}$. The inclusion of this last level of results is a consequence of the possible problems that arise during the cooperation stemming from opportunism regarding the effort supplied by the agent; in other words, one agent may supply a low effort while the other agent supplies high effort. The double super index in the nomenclature of the result types refers to the presence of two agents in the main model. The new probabilities associated with the possible results that may arise in this context are defined as follows:

$$\Pr ob[R = R^{HH} \mid E_1 = E_1^{\ H}, E_2 = E_2^{\ H}] = p_H^{\ 2}$$

$$\Pr ob[R = R^{LL} \mid E_1 = E_1^{\ H}, E_2 = E_2^{\ H}] = (1 - p_H)^2$$

$$\Pr ob[R = R^{HL} \mid E_1 = E_1^{\ H}, E_2 = E_2^{\ L}; E_1 = E_1^{\ L}, E_2 = E_2^{\ H}] = 2p_H(1 - p_H)$$

The possible contracts offered by the government to each of the agents when they cooperate are defined in the following manner:

$$W = W_i^{\ HH}; W = W_{1,}^{\ H}; W = W_2^{\ H}, si \;\; R = R^{HH}$$

$$W = W_i^{\ LL}; W = W_1^{\ L}; W = W_2^{\ L}, si \;\; R = R^{LL}$$

$$W = W_i^{LH}; W = W_1^{LH}; W = W_2^{LH}, si\ R = R^{LH} = R^{HL}$$

Where $W^{HH}$ is the high incentive each of the two agents will receive when the result is high and is equivalent to the incentive $W^H$ in model 1, the same applies for $W^{LL}$, while $W^{LH}$ denotes the incentive that each of the agents will receive when the result $R^{LH}$. With the previous equations in mind, as well as the solutions derived from model 1, the expected utility of one of the agents in terms of their effort and the incentives received from the government can be expresses as follows – assuming a high level of effort supplied:

$$\textbf{(13)}\ EU^A(E = E^H) = p_H^2 W^H + 2p_H(1 - p_H)W^{LH} + (1 - p_H)^2 W^L - v(E^H)$$

With the substitution of $W^H$ and $W^L$ for the values obtained in the first-degree condition in model 1, the following expression is attained:

$$\textbf{(14)}\ EU^A(E = E^H) = p_H{}^2\left(\overline{U} + v(E^H)\frac{1 - p_L}{p_H - p_L}\right) + 2p_H(1 - p_H)W^{LH} + (1 - p_H)^2\left(\overline{U} - v(E^H)\frac{p_L}{p_H - p_L}\right) - v(E^H)$$

If we define $\overline{W} = \frac{W^H + W^L}{2}$ and we add and subtract $\overline{W}$ in the previous equation (14), we reach the following expressions:

$$\textbf{(15)}\ EU^A(E = E^H) = p_H{}^2\left(\underline{U} + v(E^H)\frac{1 - p_L}{p_H - p_L}\right) + 2p_H(1 - p_H)\left(W^{LH} + \overline{W} - \overline{W}\right) + (1 - p_H)^2\left(\underline{U} - v(E^H)\frac{p_L}{p_H - p_L}\right) - v(E^H)$$

$$\textbf{(16)}\ EU^A(E = E^H) = \overline{U} + v(E^H) + 2\left(W^{LH} - \overline{W}\right)p_H(1 - p_H) - v(E^H) = \overline{U} + 2\left(W^{LH} - \overline{W}\right)p_H(1 - p_H)$$

Equation 16 reflects the agents´ expected utility when they cooperate, assuming a situation of high efforts. Therefore, based on this expression, and comparing it with the agent´s expected utility expression when innovation is performed individually, it can be determined when agents act cooperatively when innovating, which occurs when cooperating offers them a greater level of expected utility; this would depend on the incentive structures $W^{LH}$ received by the agent. The following proposition is thus formulated:

***Proposition**: For a level of incentives* $W^{LH} > \overline{W}$*, the innovative agents´ expected utility when they cooperate is greater than the innovative agents´ expected utility when they act individually. Therefore, under this incentive structure cooperation in innovation is fostered.*

**Proof**: It is immediately verified that when $W^{LH} > \overline{W}$, the agents´ expected utility – for a high effort – when the agents cooperate is higher than the reserve utility and consequently is greater then when they perform individually, since in this case it is limited to the reserve utility (refer to model 1).

Agents´ utility when performing individually:

$$EU^A(E = E^H) = p^H \overline{W}^H + (1 - p^H)\overline{W}^L - v(E^H) = \underline{U} + v(E^H) - v(E^H) = \underline{U}$$

Agents´ utility when cooperating:

$$EU^A(E = E^H) = \overline{U} + 2(W^{LH} - \overline{W})p_H(1 - p_H) > \overline{U} \text{ (si } W^{LH} > \overline{W}\text{), QED.}$$

Note that for a level of incentives $W^{LH} = \overline{W}$, they agent would obtain the same utility when he cooperates to develop the innovation as when he performs individually (the utility would reach the level of reserve utility). In other words, based on this outline of incentives, innovative agents would be indifferent towards cooperating.

**Discussion**

This result showcases that the principal may induce cooperation between agents if he offers a level of incentives that is sufficiently high in the case that the result of the innovation is the "intermediate result" $R^{LH}$. Mathematically this level of incentives ($W^{LH}$) should be such that $W^{LH} > \overline{W}$, in other words, it should be situated above the average incentives associated with high incentives ($W^H$) and low incentives ($W^L$) respectively. What is the economic rationality behind this incentive structure? Cooperation, independently of its nature, between agents causes the potential problem of moral hazard (Holmström, 1982; Macho-Stadler y Pérez-Castrillo, 1991, 1993). In other words, some agents may supply a low effort when they are cooperating with others, which would harm the agents who are supplying high efforts during the cooperation when the principal is not able to discriminate the remuneration according to the effort supplied – let it be reminded that an agents actions, or effort, are not observable. Given this situation, for agents to be stimulated to cooperate it is necessary to offer incentives that aid in compensating or attenuating the costs deriving from the potential behavior of moral hazard that arises during cooperation. Said stimuli are achieved if certain incentives $W^{LH}$ are established in the case that the innovation´s results are $R^{LH}$, which meets the condition that $W^{LH} > \overline{W}$. With this incentive structure, it is verified that the agent´s final expected utility in scenarios of cooperation is greater than the expected utility when the agents perform individually; therefore, the agent obtains benefits from cooperation in innovation. Additionally, these gains will be greater, the greater the difference between $W^{LH}$ y $\overline{W}$. It can be thus concluded that the technological policy can stimulate cooperation in innovation through an adequate design of the incentives program.

## 4. Conclusions, limitations and future investigation

This paper has studied the technological policy´s capacity to promote cooperative behavior between firms in order to develop innovation activities from a theoretical-formal perspective. To accomplish this, we have built upon the foundations of the principal-agent model the relationship that is established between a principal – in this case the government, who is responsible for the elaboration of the program of technological policy – and the agent – the firms and organizations in charge of developing innovations – with the objective of determining the incentive structure that the principal must design in order to foster the cooperation in innovation between the agents. The analytical results have highlighted the existence of a certain incentive threshold upon which cooperation in innovation between agents can be promoted. Therefore, it is proven that the technological policy can produce variations in the behavior of the firms in reference to the development of innovation activities.

### 4.1 Theoretical research implications

One of the implications of this paper is that a new path of theoretical-analytical research is forged in the field of technological policy and (cooperation in) innovation. To the best of our knowledge, the studies carried out in this particular area have been limited to a purely empirical focus. Therefore, the study of this phenomenon through the development of theoretical models will contribute towards enriching and systematizing this field of study. In this sense, we have examined that a work exists, albeit still in electronic format (Quynh Le et al., 2012), which analyzes the relationship between technological policy and innovation through evolutionary game theory. It is our attempt, therefore, to further the research and development of a new more formal approach, which allows us to reach a greater understanding of the relationship between technological policy and innovation.

### 4.2 Policy implications

Some implications that can be derived from our results, from a practical standpoint, are as follows: First of all, the governments, through an appropriate R&D incentives system can stimulate and favor cooperation between innovative firms. In particular, higher incentives (e.g., higher R&D subsidies) help to reduce collaboration costs, related to the moral hazard problem and the coordination costs between agents, thus facilitating the cooperation between them. Secondly, and related with the prior implication, is the quantity or volume of these public R&D subsidies, especially in those programs in which cooperation is a requisite *sine qua non,* in order to avoid income-seeking behaviors. In other words, if the programs offer a very generous financing, it can become an objective itself, and therefore, agents cooperate mainly to seek income and not because they truly want to cooperate. Moreover, this behavior can also influence the completion of the technological objectives established in such projects since the generation of an artificial cooperation does not guarantee the development of the project given the lack of authentic and genuine interest in its conclusion. Related to the above, some works (Heijs, 2003) have pointed out the existence of a free-riding problem in relation to the concession of low-interest public loans to develop R&D projects, presenting evidence that the beneficiaries of such loans may carry out the same level of innovative activities without public funds and that these firms also obtain a lesser level of proposed technical or commercial objectives. Thirdly, and from a dynamic perspective, R&D public aid programs to foster R&D collaborative agreements can be adjusted according to relationship that exists between collaborators and in this sense can contribute towards optimizing the social resources allocated to technological activities. In other words, for those agents who maintain a sustainable, long-term cooperation it is not necessary such a level of incentives as great as those who are being initiated in cooperation as a result of the trust and reputation that has developed over the course of the cooperation that will attenuate the initial costs of cooperating above mentioned. Also this contributes to mitigate the self-selection bias towards the participation in such R&D public programs where those firms that have received funds and been involved in a cooperation process over a long period of time have some advantages to participate again in those programs in relation to firms that never have cooperated. Finally, it should be noted that the efficiency of the incentives program to stimulate technological cooperation depends on the existing cooperative culture. In this sense, in environments with a higher predisposition towards working collaboratively, the amount of incentives necessary to stimulate cooperation should be inferior to those environments where there is a lesser cooperative culture.

### 4.3 Limitations and future investigation

Evidently all works are subject to limitations, which are simultaneously new opportunities for advancement and gaining greater depth in the investigation. As to our model´s limitations, we have considered that agents can only perfectly infer the effort and behavior each has supplied once the project is completed and the result has been evaluated. This limitation opens the possibility of a new theoretical development and the extension of the model, introducing an ex-ante monitoring mechanism either interested or uninterested (costly internal monitoring). In other words, said supervision can consist of various monitoring mechanisms, including internal monitoring, mutual control, or external monitoring carried out by a third-party. On the other hand, the results deriving from our model also opens the path for empirical studies. Thus, the existence of a certain R&D public aid threshold upon which the ratio of cooperation in innovation increases can be verified. Based on the previous verification, another possible empirical extension could be the comparative analysis of firms from different countries to evaluate whether this R&D public aid threshold to stimulate cooperation varies inter countries; should any differences exist, it would be an indicator that cultural factors influence the tendency to cooperate or not.

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