Nonprofit and for-profit competition (and cooperation) in basic research

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Abstract

We develop a model whereby for-profit organizations could invest in doing basic research and/or they can wait for or, help fund, a nonprofit entity to perform such research. The nonprofit may also receive funds from a social welfare maximizer and must disseminate freely the knowledge it creates. A for-profit, when such knowledge is not publicly available and found through its own research, may license it as a trade secret. We find the conditions under which for-profits would invest in such basic research. We also derive conditions under which nonprofit research may “crowd-out” for-profit basic research. Lastly, we show that independent nonprofit research labs may be a useful vehicle for governments to stimulate for-profit entities to fund basic research.

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1. Introduction

Basic research, also known as pure research or fundamental research, is the “systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind … it is farsighted, high payoff research that provides the basis for technological progress” (Legal Information Institute, 32 CFR 272.3). It “results in general knowledge” which “provides the means of answering a large number of important practical problems” (NSF, 1953). In the U.S. in 2011, 74.1 $bil was expended on such research of which: 13 $bil was performed in industry; $40 bil done in universities and colleges, and; $9.5 bil was executed in “other nonprofits” (NSF, 2013). $15 billion of such research in that same year was funded by industry. While these figures are small in comparison to the total R&D spend in the U.S. at that time of $429.1 billion (of which industry does almost $300 billion, NSF, 2013), basic research is regarded by many as an engine of technological progress (as suggested in the above quotes and in Nelson, 1959, Mansfield, 1980, and many others). Griliches (1986) found in his examination of data from 1,000 U.S. manufacturing firms in the 1970s found that 1) basic research was a more important determinant of productivity than other types of R&D and, 2) privately financed R&D was more effective at the firm level than federally financed. In this study we seek to understand better why profit motivated organizations would fund and perform basic research and how that investment is affected by the existence of nonprofit basic research funders and performers. Nonprofits as such may be a nongovernmental vehicle for the remedy of (or exacerbate) some market failure in the innovation ecosystem which could justify their nontax status.

Nonprofits and how they interact with the for-profit sector should be of concern to economists and policymakers as this form of organization is prominent in important sectors such as healthcare and education. Nonprofits in the U.S. made up 5.4% of the GDP and 10% of jobs in 2010 (Urban Institute, www.urban.org/nonprofits).2 In, and of themselves, nonprofits are interesting organizations with different accountabilities, sources of funds and motives than for-profits. The differing motivations of organizations have been examined for their impact on whether and how basic research is conducted (Aghion, Dewatripont and Stein, 2008, Lacetera, 2009). We model nonprofit research organizations as ones which must use any surplus towards “further production of the services that the organization was formed to provide” (Hansmann, 1980, p. 838). This means that the nonprofit research performer applies all the funds it is granted towards conducting (in this case) basic research.

There are many reasons to believe that for-profits (FPs) would not be very interested in making investments in basic research (enumerated in: Nelson, 1959; Arrow,). This lack of motivation can

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2 More specifically, in the U.S., those organizations classified under section 501 (c) of the U.S. Internal Revenue Service code – of which there are 1.6 million.
be rationalized by: appropriability issues due to the ease of the new knowledge spilling over to rival firms; the high degree of uncertainty that the new knowledge would ultimately yield profitable new processes or products, and; the long lags between the investment and the possible returns. The existence of nonprofit basic research performers and funders may make such investments redundant.\(^3\) Nelson (1959), Rosenberg (1999) and Cohen and Levinthal (1989), however, do find some reasons for private for-profit investment in basic research and we incorporate these (among others) into our analysis. Cohen and Levinthal introduce how doing basic research can help firms absorb the knowledge created outside the firm. They model this using spillovers we incorporate this feature in our model in a more reduced form via a cost function which exhibits synergies between doing the research and the subsequent development work. Rosenberg reports that for-profit entities think of basic research as a long term investment and can be induced to make such investments if there is prospect for eventual returns through useful products generated from such research. Thus the strength of a firm’s downstream commercialization capabilities improves the prospect of such investments. We, consequently include a development stage into our analysis. We also introduce a new inducement for private for-profit investment in basic R&D – the ability to keep any new knowledge created a trade secret which can subsequently be licensed.

The model we develop builds on a rich tradition of R&D races, most closely with that of Harris and Vickers (1985) and especially Gross and Shapiro (1987). We, however, add a nonprofit entity which plays in the first stage, the research stage, and not in the development stage. This study could also be considered an extension of the more recent work of DeFraja (2016) who examines the problem of a government allocating research funds which amongst research institutions of differing reputations and efficiency in the production of research. Within that problem he analyzed how research institutions would allocate their finds amongst basic and applied research. In our model we distinguish between organizations which rely on government or nongovernmental funds and specialize in basic research and, self-financed for-profit firms which could conduct both basic and applied research. The work of Aghion et. al. and Lacetera suggests that that specialization may occur due to labor market considerations we rationalize the specialization of nonprofit basic research performers based on legal considerations (i.e., the ability to keep trade secrets). Our models (that of DeFraja and ours) also share the feature that those entities which perform both basic and applied research exhibit synergies in doing so. We subsequently extend our model to one where the for-profit firm can invest simultaneously in the NPs research while also investing and performing its own basic research.

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\(^3\) Many government or nonprofit foundation funders of basic research require that the investigators submit for publication and otherwise disseminate significant results of the research as well as share with other researchers their primary data (see, for example the policies of: National Science Foundation, [http://www.nsf.gov/pubs/policydocs/pappguide/nsf15001/aag_6.jsp#VID4](http://www.nsf.gov/pubs/policydocs/pappguide/nsf15001/aag_6.jsp#VID4), National Institutes of Health, [https://grants.nih.gov/policy/sharing.htm](https://grants.nih.gov/policy/sharing.htm), and the Gates Foundation, [http://www.gatesfoundation.org/How-We-Work/General-Information/Open-Access-Policy](http://www.gatesfoundation.org/How-We-Work/General-Information/Open-Access-Policy)).
We first find conditions under which a for-profit would engage in basic research at all. This condition turns out to be relatively restrictive. We then find conditions under which nonprofit research has a crowding out effect on for-profit investment in basic research. This is due to three effects of nonprofits: 1) that it makes the for-profit firm’s investments unnecessary as the results are obtained (from its perspective) for “free”; 2) it reduces the “carrot” of the for-profit’s ability to out-license the trade secret which would result from its successful basic research as the nonprofit disseminates such knowledge freely, and; 3) it reduces the “stick” of the for-profit having to pay in-licensing fees should it be unsuccessful and another for-profit is successful in its research program. These disincentives come about from the nature of the mission of the nonprofit and its funding constraints – that the results of the research be freely disseminated. Also, we find that the generality of the basic research is an incentive for a welfare maximizer to fund more basic research at the nonprofit when the number of industries and their research intensity is low. This is due to that research being redundant when private industries are already very active and there are a large number of such industries. Finally, we discover that an independent nonprofit research lab can be a useful mechanism for a welfare maximizer to encourage private sector investment in basic research.

The following report on this study is organized as follows. We first present our mixed duopoly model of a for-profit investing in basic research in an environment where there is a nonprofit entity also conducting that research. We formulate and analyze the policymaker’s problem of funding the research of the nonprofit research performer. We then examine in detail the comparative statics of the derived equilibrium basic research intensity. Subsequently, we extend the model to one where the basic research is more general, where there are many for-profits in unrelated industries also possibly pursuing that basic research. This introduces the possibility of licensing among the for-profits. In the penultimate section we introduce the ability of the for-profit to invest in the nonprofit’s performance of basic research. We discuss how that and the existence of an independent nonprofit research performer change the possibilities for the welfare maximizer. Finally we summarize and discuss the results and present possible extensions.

2. The Model

In our model the for-profit (FP) firms and nonprofit (NP) types of entities can both conduct basic research. Only the for-profit firms continue on to do development work of new products and processes based on the new knowledge generated from successful basic research. The nonprofit entity is governed by its charter and by funding guidelines which require it to use all its available funds towards basic research (see the examples in footnote 3) and to publicly disseminate the results of its (successful) research. Thus this new knowledge freely spillover to all firms if successfully created by the nonprofit. It is assumed for our analysis that the for-profit entities
involved in basic research have knowledge of the subsequent development intensity and success probability \((d, 0 < d < 1)\) required to convert the successful basic research into a new product or process that would generate profits \((\pi)\). That is, conditional on the success of the basic research (with probability \(r\)), the development intensity is determined. What the optimal level of development effort and its probability of success is known in advance. Such an assumption allows us to focus on the basic research intensity \((r)\). We first examine the case of a mixed duopoly – where there is one nonprofit research performer and one for-profit research and development performer.

2.1.1 The mixed duopoly

In the case where there is one nonprofit entity (with success probability of basic research of \(r_N\)) and one for-profit firm the payoff for the for-profit firm \(i\) in industry \(i\) from conducting a certain research effort \(r_i (0 < r_i < 1)\) and subsequent development intensity \((d_i, 0 < d_i < 1)\) is,

\[
\Pi_i = r_i d_i \pi_i + (1 - r_i)r_N d_i \pi_i - \frac{c}{2} r_i^2 + \gamma r_i d_i \tag{1}
\]

where, the first two terms are the expected profits if the for-profit and nonprofit are successful, respectively. The last two terms are the costs of conducting research and the cost of development which are not separable from the costs of research. We ignore the costs of development that are separable from the research as they do not affect the problem under consideration. The cost of basic research is assumed quadratic function of its probability such that obtaining certain success would be prohibitively expensive. Such assumptions on the costs also ensures that second order conditions for optimality are realized. The cost of research and development also exhibits the synergies discussed in Cohen and Levinthal (1989) between research effort and development intensity which in our model is given by the last term in the cost function above with the coefficient \(\gamma\). Rather than explicitly modelling the spillovers from research to development as in Cohen and Levinthal we reduce this effect to a cost savings in development which the greater understanding of the basic knowledge the research process provides.

The first term in the above payoff function is the expected payoff in its own product market if the firm \(i\)'s own research is successful. The second term shows the expected product market profits if its own research is unsuccessful but the nonprofit is successful in its research program.

The above payoff function is a concave function of the basic research success probability \(r_i\) with a first order condition of

\[
\frac{\partial \Pi_i}{\partial r_i} = d_i \pi_i - r_N d_i \pi_i - c * r_i^* + \gamma d_i = 0 \tag{2}
\]
which implies that, \( r_i^* = \frac{d_1}{c} [\pi_i (1 - r_N) + \gamma] \). \( (2)' \)

The second order condition \( \frac{\partial^2 \pi_i}{\partial r_i^2} = -c \) is negative so that the solution to the above provides a research intensity which maximizes the profits. One can see directly from the above condition that the effect of nonprofit research intensity on that of the for-profit is negative, \( \frac{\partial r^*}{\partial r_N} = \frac{-d_\pi}{c} \). That is, there would be a crowding-out effect of the nonprofit’s research investment on the investment of the for-profit. The interpretation is straightforward – there is less need for the for-profit to invest if the nonprofit will give it the results for “free”.

We now turn to the problem of an entity considering the funding of the nonprofit’s research.

2.1.2 Social Welfare

In this section we examine the problem of the policymaker who seeks to induce the intensity of basic research which would maximize social welfare. The instrument of the policy would be the funding of the nonprofit \( r_N \). Say that the new invention generates a social value of \( V \) upon successful development in an industry \( i \) (see Mansfield, et.al., 1977, for a comparison of numerical values of social versus private rates of return, generally \( V \) would be larger than \( \pi \)). The welfare function to be maximized would then be

\[
W = (r_N + r_i - r_N) dV - \frac{c_N r_N^2}{2} - \frac{c r_i^2}{2} + \gamma r_i d \quad (3)
\]

Note that in the above we have assumed that the nonprofit entity incurs costs of basic research in a similar fashion to the for-profits with the exception that it does not conduct development work and therefore cannot capture the synergies from that. Also, the social costs of funding basic research conducted by the nonprofit, \( c_N \), may include the distortion costs to the economy of government funding. That is, the policymaker wants that an entity conducting basic research is successful and cares which entity performs the research only to the extent that it is done efficiently.\(^4\) In such an environment the policy maker would want to encourage licensing as it

\(^4\) An important issue is the communication between scientists for an interesting analysis of this issue see Mandler (2017, forthcoming).
expands the social benefits incurred from the research and the model above assumes that the licensing takes place. The licensing fees would then simply be internal transfers within the economy.

The policymaker then funds the research intensity of the nonprofit entity in order to maximize the above welfare function taking into consideration how it affects the research program of the for-profit,

$$\frac{\partial W}{\partial r_N} = -c_N r_N^* + (1 - r_l) dV = 0 . \quad (4)$$

Substituting (4) into (2)' the equilibrium \( r_i \) can then be fully characterized by market parameters as

$$r_i^* = \frac{d}{cc_N - d^2\pi V} [c_N (\pi + \gamma) - d\pi V] . \quad (5)$$

A second order condition for the equilibrium requires that \( c_N - d^2\pi V > 0 \). This then implies,

**Proposition 1:** A for-profit firm in a mixed duopoly equilibrium would invest in research if,

$$c_N (\pi + \gamma) > d\pi V$$

From (5) the above condition ensures that \( 0 < r_i^* \). Since, the probabilities must be \( 0 < r_i^* < 1 \) that also implies, \( d(\pi + \gamma) < c \). Rewriting the condition in Proposition 1 so the nonprofit parameters are on one side, the condition becomes \( \frac{\pi + \gamma}{d\pi} > \frac{V}{c_N} \). As Mansfield (1977) has found that the social rate of return higher than the private rate of return for many innovations and in some cases substantially so, this condition would be hard to satisfy. This may explain why basic research is not often performed in for-profit entities. With a substantially higher social value \( V \), the public investment would be relatively large and as that is a substitute for private investment the for-profit finds that it is not worthwhile to invest in research. One of the comparative statics are clear from the above, the greater synergies of research with development intensity the larger the equilibrium for-profit research intensity.

Substituting \( r_i^* \) into (4) yields the equilibrium social welfare maximizers funded research intensity,
Comparing the two research intensities (5) and (6) the intensity of the nonprofit would exceed that funded and performed by the for-profit if, \( V > \frac{c_N(\pi + \gamma)}{c - dV} \). In other words, \( r_N^{**} > r_f^* \) whenever the costs of private funding, \( c \), the development intensity, \( d \) and the social value, \( V \) are large, and; the costs of public funding, \( c_N \), the private surplus, \( \pi \), and the synergies between development and research, \( \gamma \), are low. We now examine the case where the basic research is applicable to a wider array of industries.

2.2.1 On the generality of the research – an oligopoly with a nonprofit fringe

We now extend the above model to one where there are \( n+1 \) for-profit firms in different industries which find the basic research of interest. As before, the nonprofit freely disseminates the results of its research but now to all \( n+1 \) firms in the different industries which find the new knowledge useful. The number of industries, \( n+1 \), can be interpreted as a measure of the generality of the basic research. That is, it is a measure of the “large number of important practical problems” described in the NSF definition of basic research (NSF, 1953). The for-profits, in contrast, can maintain the knowledge generated through a successful basic research program as a trade secret which it can license for a proportion (\( \alpha, 0 < \alpha < 1 \)) of the in-licensee’s profits. Those licensing fees are generated by for-profit firms upon successful basic research by one of the for-profit research organizations and upon successful subsequent development effort. Such licensing fees cannot be obtained by any for-profit if the nonprofit is successful and disseminates the results of its research. The payoff for a representative firm \( i \) in industry \( i \) from conducting a certain research effort \( r_i (0 < r_i < 1) \) is,

\[
\Pi_i = r_id_i\pi_i + (1-r_i)r_Nd_i\pi_i + \sum_{j \neq i} (1-r_j)(1-r_N)(1-r_j)^{n-1}r_jd_i(1-\alpha)\pi_i \\
+ \sum_{j \neq i} (1-r_j)^n(1-r_N)r_i d_j\alpha\pi_j - \frac{c}{2}r_i^2 + \gamma r_i d_i \tag{7}
\]

The above payoff function has the same first two terms as in the mixed duopoly model and has the same last two cost function terms. The additional third term represents the expected product market profits less the licensing fee in the case where the firm \( i \) and the nonprofit have both been
unsuccessful but one of the other for-profits is successful. Thus we capture the possibility of for-profit entities keeping the knowledge generated by basic research a trade secret and we assume they are able to license such trade secrets at a rate of \( \alpha \) of the subsequent profits \((0 \leq \alpha \leq 1)\). Assumed here is that the trade secret is of value if only one for-profit is successful (i.e., that in the licensing market there is Bertrand competition of a homogeneous product if more than one for-profit is successful). The fourth term is the revenue source of expected licensing fees from other for-profits if firm \( i \) is successful and the nonprofit together with all other for-profits have been unsuccessful in their research. If any two or more for-profits are successful it is assumed that the ensuing price competition for licensing eliminates the licensing fees.

The above payoff function is a concave function of the basic research success probability \( r_i \) with a first order condition of

\[
\frac{\partial \Pi_i}{\partial r_i} = d_i \pi_i - r_N d_i \pi_i - \sum_{j \neq i} (1 - r_N)(1 - r_j)^{n-1} r_j d_i (1 - \alpha) \pi_i + \sum_{j \neq i} (1 - r_j)^n (1 - r_N) d_j \alpha \pi_j \\
- c \times r_i^* + \gamma d_i = 0
\]

(8)

The above condition implies that although the for-profit entities do not compete in the product market their basic research efforts are strategic substitutes \((\frac{\partial r_i}{\partial r_j} < 0, \forall j \neq i)\). This suggests that the equilibrium research intensities of the for-profit entities would involve over-investment using a producers’ surplus criterion.

To see the effects of our market parameters more clearly assume that the \( n+1 \) industries are all symmetric \((r_j = r_i = r, d_j = d_i = d, \pi_j = \pi_i = \pi)\) the first order condition then becomes

\[
d \gamma - c r^* + d \pi (1 - r_N)[1 - (1 - r^*)^{n-1}n(r^* - \alpha)] = 0
\]

(9)

As we have assumed that \( r \) is less than one, this means that \( c > d \pi (1 - r_N)[1 - (1 - r^*)^{n-1}n(r^* - \alpha)] + d \gamma \). Clearly, the research intensity of the nonprofit entity has an impact on the for-profit’s research intensity so we turn our focus onto this apparently socially beneficial activity.
On the effect of nonprofit research

One issue that has received some attention in the literature is whether public R&D investment crowds out or complements private for-profit investment (see the survey in, David, Hall and Toole, 2000). In the mixed duopoly case above in Section 2.1 this comparative static was straightforward – nonprofit research discouraged for-profit research. In the more general case with \( n+1 \) industries this comparative static is not so clear-cut. Implicitly differentiating the first order condition (9) with respect to the nonprofit’s research intensity we obtain

\[
\frac{\partial r^*}{\partial r_n} = \frac{-d\pi[1 - n(1 - r^*)^{n-1}(r^* - \alpha)]}{c + nd\pi(1 - r_n)(1 - r^*)^{n-2}[1 - \alpha - n(r^* - \alpha)]}
\]  

(10)

Based on this strategic interaction we find,

**Proposition 2:** Nonprofit basic research crowds-out for-profit research if and only if

\[
\frac{1-n(1-r^*)^n-1(r^*-\alpha)}{c+nd\pi(1-r_n)(1-r^*)^{n-2}[1-\alpha-n(r^*-\alpha)]} > 0.
\]

The condition in the above Proposition shows that whether there is a crowding-out effect of publicly funded research on privately performed research in this more general setting depends on a complicated relationship between market parameters. Such a condition can help explain the mixture of results in empirical studies on whether public R&D crowds-out or substitutes private R&D (David, Hall and Toole, 2000).

Where the expression in condition (10) equals zero is plotted for the values of \( d = 0.1, r_n = 0.25, \pi = 100, c = 2 \) for both \( n=4 \) and \( n=10 \) in Figure 1. From that graph one can observe the parameter region where the for-profits consider the research of the nonprofit a strategic complement, that is, for lower licensing rates (\( \alpha \) small) and higher probabilities of research success (\( 0.2 \leq r \leq 0.5 \)) in the lower right of the graph. In that parameter region the denominator of the expression in (10) becomes negative and changes the sign of (10) to positive. In this case the chances of receiving licensing royalties are low as there are many for profit rivals (the contours are plotted for \( n=4 \) and \( n=10 \)) multiple for-profits are likely to succeed. The licensing royalty rates are also small so there is little licensing revenues to be had (or to be paid out). The success probability of the for-profits in this region are similar to that of the nonprofit. Increases in the nonprofit investment in this region ensures more that the for-profits can continue on to the development stage and raise the expected profits from that. Thus increases in publicly funded research increase the overall profitability of the venture and stimulates more private research. We have also plotted on that graph in Figure 1 the combinations of licensing rates and research intensities which satisfy the
equilibrium condition (9) for the same parameters of costs, profits and development probabilities of success, \( n=10 \) and \( \gamma=1 \). One can see that the equilibrium exists for fairly high licensing rates and that most (but not necessarily all) of the equilibria exist in the strategic substitute realm.

**Figure 1** Type of strategic interaction of public and private research by research intensity and licensing rate (\( d = 0.1, r_N = 0.25, \pi = 100, c = 2 \))
2.2.2 Social Welfare

In this section we examine the problem of the policymaker who seeks to induce the intensity of basic research which would maximize social welfare. This is the problem examined by DeFraja (2016) albeit we are examining the issue in the presence of self-financed for-profit R&D performers. Say that each new invention generates a social value of $V_i$ upon successful development in an industry $i$ (see Mansfield, et.al., 1977, for a comparison of numerical values of social versus private rates of return, generally $V$ would be larger than $\pi$). The welfare function to be maximized would then be

$$W = (1 - (1 - r_N)(1 - r_i)^{n+1}) \sum_{l} d_i V_l - \frac{c_N}{2} r_N^2 - \frac{c}{2} \sum_{l} r_i^2 + \sum_{l} \gamma r_i d_i$$  \hspace{1cm} (11)$$

The benefits of successful research are obtained by the welfare maximizer when at least one research performer is successful. Hence the first factor in the expression above is one minus the probability that no one enterprise is successful. From a social welfare point of view multiple successes are redundant. Those expected social benefits are achieved upon the successful conclusion of development by the for-profit entities the sum of the expected social values, $dV$. Note that in the above we have assumed that the nonprofit entity incurs costs of basic research in a similar fashion to the for-profits with the exception that it does not conduct development work and therefore cannot capture the synergies from that. Also, the social costs are assumed to be the same as the private costs. That is, the policymaker wants that an entity conducting basic research is successful and cares which entity performs the research only to the extent that it is done efficiently. In such an environment the policy maker would want to encourage licensing as it expands the social benefits incurred from the research and the model above assumes that the licensing takes place. The licensing fees would then simply be internal transfers within the economy.

The policymaker then funds the research intensity of the nonprofit entity in order to maximize the above welfare function taking into consideration how it affects the research programs of the for-profits. Again, when the industries are symmetric,

$$\frac{\partial W}{\partial r_N} = c_N r_N^* + (1 - r)^{n+1}(n + 1)dV = 0$$ \hspace{1cm} (12)$$
where the second order condition is satisfied as \( \frac{\partial^2 W}{\partial r^2} = -c_N < 0 \). The welfare maximizing basic research funding of the nonprofit \( r_N^* = \frac{(n+1)}{c_N} (1 - r)^{n+1} dV \) is clearly larger when that research is of greater expected social value and the intensity is lower when it is more costly to conduct. The effect of the number of industries to which the research is applicable on the socially optimal level of nonprofit research funding is interesting. The derivative of \( r_N^* \) with respect to \( n \) is

\[
\frac{\partial r_N^*}{\partial n} = \frac{dV}{c_N} (1 - r)^{n+1}[1 + (n + 1)\ln(1 - r)]
\]

which means that for larger \( r \) and larger \( n \), \( n \) has a negative effect on \( r_N^* \), i.e., it implies the following,

**Proposition 3:** The generality of the basic research (the number of industries, \( n \), which would benefit from the new knowledge) increases the nonprofit investment in that research iff

\[
(1 - r)^{n+1}[1 + (n + 1)\ln(1 - r)] > 0.
\]

For example, with an \( r = 5\% \) and \( n = 3 \) and increase of \( n \) to \( n = 4 \) increases the optimal public investment in research. However, if \( r = 20\% \) and \( n = 5 \), an increase of the applicability to \( n = 6 \) would actually decrease the optimal public investment. When \( n \) and \( r \) are both low the probability of a for-profit research success are low and the additional applicability of greater \( n \) increases the benefit to society of publicly funded research and thereby encourages it. When \( n \) and \( r \) are relatively high, however, then the probability of publicly funded research being redundant becomes high. In this case, additional industries to which the research applies simply increases that probability of redundancy and decreases the incentive to invest in publicly funded research.

### 3. For-profit funding of nonprofit research

In this section we examine the effect of an independent nonprofit research performing institution. That is, in the previous sections the nonprofit research entity obtained its entire funding from a welfare maximizer. This sort of research institution could be, for example, a government run research agency. In this section we open up the possibility of research funding to the nonprofit could be also from private (for-profit) sources. An example, of such an institution could be a research university. Say, in addition to performing its own basic research, a for-profit may consider the partial funding of research to be conducted by a nonprofit. In 2015 more than $4bil of the total $68 bil in research conducted at universities was funded by corporate sources (NSF, 2015).
In this way the FP can contribute to the diversity of laboratories working on the risky research project. In essence, it can make sure that it has “two kicks at the can” and can enjoy a greater probability that someone succeeds in the basic research. The downside for the FP is that with the greater success of the NP there would be a smaller probability of the FP obtaining sole ownership of the knowledge and thereby reducing the expected licensing revenues (albeit it also reduces the probability of paying out licensing fees to other FPs). To illustrate the effect of this change let us modify the mixed duopoly model of the type in Section 2.1.

In this case, the profit function of a for-profit (say, firm 1) considering investing in either or both of its own research \(r_1\) and/or funding some of the nonprofit’s research \(r_{N1}\) we modify (1) to,

\[
\Pi_1 = r_1 d_1 \pi_1 + (1 - r_1)(r_N + r_{N1})d_1 \pi_1 - \frac{c}{2}(r_1^2 + r_{N1}^2) + \gamma r_1 d_1 \quad (13)
\]

that is, the costs of funding research for the for-profit are the same whether it performs it itself or whether it funds that research within the nonprofit research performer. Synergies with development, however, are only obtained from inhouse research.

Firm 1 would then maximize over the two variables \(r_1\) and \(r_{N1}\) which have the first order conditions,

\[
\frac{\partial \Pi_1}{\partial r_1} = d_1 \pi_1 (1 - r_N - r_{N1}) - c * r_1^* + \gamma d_1 = 0 \quad (14)
\]

and,

\[
\frac{\partial \Pi_1}{\partial r_{N1}} = d_1 \pi_1 (1 - r_1) - c * r_{N1}^* = 0 \quad (15)
\]

and the second order conditions, \(\frac{\partial^2 \Pi_1}{\partial r_1^2} = \frac{\partial^2 \Pi_1}{\partial r_{N1}^2} = -c < 0 \) and \(\frac{\partial^2 \Pi_1}{\partial r_1^2 \partial r_{N1}^2} - \left(\frac{\partial^2 \Pi_1}{\partial r_1 \partial r_{N1}}\right)^2 = c^2 - d^2 \pi^2 > 0\).

Observe from the above that the two forms of research funded by the for-profit are substitutes to one another. Solving (14) and (15) yields the optimal inhouse and subcontracted levels of research,

\[
r_1^* = \frac{d[c \pi(1-r_N)+cy-d \pi^2]}{c^2-d^2 \pi^2} \quad \text{and} \quad r_{N1}^* = \frac{d[c \pi(1-r_N)-d \pi(1-r_N)]}{c^2-d^2 \pi^2} \quad (16)
\]

This implies that \(r_1^* > r_{N1}^* \) if \(r_N^* < \frac{\gamma}{\pi}\). That is, the inhouse research will be larger when the synergies are large relative to the profits and the research funding from the welfare maximizer is small.
The welfare maximizer maximizes a somewhat modified version of (4),
\[ W = (r_N + r_{N1} + r_1) d_1 V_1 - \frac{C_N}{2} r_N^2 - \frac{C}{2} (r_{N1} + r_1^2) + \gamma r_1 d_1 \]  
(17)

but this does not change the welfare maximizers first order condition from that in (4). The
equilibrium investments are the solution of the system,
\[ r_1^* = \frac{d[c\pi(1-r_N)+c\gamma-d\pi^2]}{c^2-d^2 \pi^2}, \quad \text{and} \quad r_N^* = \frac{d_1 V}{c_N} (1 - \gamma). \]  
(18)

As can be seen from the above system of equations when there is a crowding-out effect of the
publicly funded research of the for-profit conducted research \( r_i \) then the for-profit funded
research performed by the nonprofit \( r_{N1} \) increases. Consequently, a welfare maximizer wishing
to increase the funding of basic research which disseminates its results publicly may find it useful
to have an independent nonprofit research institution which accepts both public and for-profit
funding. With such an institution the welfare maximizer’s investment in research can then
stimulate for-profits to also invest more in research that would ultimately be disseminated publicly.

The equilibrium research levels (the solution to (18) and then (16)) are then,
\[ r_1^{**} = \frac{d[cc_N\pi - c_N d_N^2 \pi^2 - c_N d \pi V + cc_N Y]}{c^2 c_N - c_N d_N^2 \pi^2 - c_N d \pi V}, \quad r_{N1}^{**} = \frac{dpc_N[c - d\pi - dy]}{c^2 c_N - c_N d_N^2 \pi^2 - c_N d \pi V}, \quad \text{and} \quad r_N^{**} = \frac{dV[c - d\pi - dy]}{c^2 c_N - c_N d_N^2 \pi^2 - c_N d \pi V}. \]

One can see directly from the above that \( r_N^{**} > r_{N1}^{**} \) whenever \( \text{Vc} > \pi c_N \). That is, the publicly
funded research would be greater when the social value of the discovery is greater than the private
surplus and when the costs of public funding are lower than the costs of private funding. Also, the
private funds to inhouse research would exceed that of the privately funded nonprofit performed
research \( r_1^{**} > r_{N1}^{**} \) whenever \( c_N d \pi V - cc_N Y < d\pi c_N Y \). That is, more of the funding would be
directed by the for-profit towards its inhouse research as the synergies with development are
higher, the cost of the public funds is higher, and when the social benefit of the discovery is lower.
Clearly, the comparative static effect of the cost of public funds and the social benefit on the
relative funding from the for-profit occur due to the effects of those parameters on the public
funding of research and the for-profit reaction to that.
Discussion of Results

In this study we have developed a model of basic research which could be funded through either a welfare maximizer and/or a for-profit organization and could be performed by a nonprofit organization or a for-profit. When the nonprofit is successful in its research it publicly disseminates the new knowledge created. For-profit firms may then conduct development and realize the profits when that development work is successful. When the for-profit is successful in research it then gains synergies with its own development work. The for-profit may also license the knowledge it has created to other for-profits as a trade secret and then realize licensing revenues once its in-licensors have successfully completed their development work. We examine the questions: under what conditions would for-profits invest in basic research? and, when would publicly funded research crowd-out the for-profit research? We also analyze when a for-profit would fund a nonprofit to conduct basic research.

Some of the answers to the above questions are not clear-cut but turn out to be dependent on market conditions. We find conditions under which a for-profit will engage in basic research on its own. This condition turns out to be fairly restrictive which may explain the paucity of for-profit entities that engage in this activity. We also find a condition under which publicly funded research would “crowd-out” for-profit research. We find that the crowding-out effect occurs when the synergies between research and development are low, and the costs of conducting research and the licensing costs are high. This could explain why empirical studies have come to differing conclusions on those issues (see the survey in David, Hall and Toole, 2000). We also examined how the generality of research affects both the private and public investment in research. That is, we studied the effect of the research being applicable in a number of different industries. Public funding (i.e., that of a welfare maximizer) increased with the number of industries when the number of industries and the research intensities of the for-profits were both low. This is due to that public investment being likely to be redundant when there are a larger number of industries which are in equilibrium very active in research.

We additionally discover that the existence of an independent nonprofit research performing institution can help a welfare maximizer stimulate more research the new knowledge of which is publicly disseminated. Under those conditions where a welfare maximizer’s (say, public) investment in research might otherwise crowd-out for-profit investment in research, allowing for for-profit investment in an independent nonprofit research institution results in the public investment encouraging additional investment from the private sector. In this way a government may find independent nonprofit research institutions a useful vehicle to stimulate innovation in the economy,
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