Research Calls, Competition for Funding and Inefficiency*

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Abstract

Research groups spend time and resources in the process of applying for funding. This issue raises important questions regarding inefficiency and whether the currently used funding mechanisms are adequate. This paper aims to identify ways of reducing the inefficiency and the waste of resources when making research funding calls. We look at four ways of reducing inefficiency. Inefficiency decreases when: (1) the most productive research groups are favoured over the less productive ones, (2) the call is restricted to a small number of research groups actively working on the subject of the call, (3) the funding process is less dependent on the amount of effort spent on fund-seeking activities by the research groups, and (4) the number of research groups competing in the same call is small. However, not all these mechanisms are equally powerful or easy to implement. Our results suggest that (1) reducing the dependence of the funding process on funding activities' efforts, or (2) reducing the number of research groups by narrowing the subject of the call to groups that are very active in the call's subject might be particularly effective in reducing inefficiency.

Keywords: research funding, funding competition, random funding, inefficiency.

1. Introduction

Evaluation can be defined as a systematic process to assess the efficiency of policies, programmes and projects (e.g. quality, see Marjanovic, Hanney and Wooding, 2010). One should expect that such a process fulfils exactly what it demands itself: efficiency. According to Hackett and Chubin (2003) "peer review is asked to be effective – to recommend projects that would benefit the field and confer some greater social benefit, to offer advice to proposers, to circulate ideas within a community, and the like. Peer review is also asked to be efficient, to do all this at very low cost, with cost measured in terms of dollars spent on reviews (infrastructure, travel, reviewer compensation) and hours expended by proposal writers and reviewers" (p. 15). Since evaluation processes at funding agencies have been assessed as (partly inefficient), Wood (1997) and the Parliamentary Office of Science and Technology

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(2002) make some recommendations for improving their efficiency (e.g. by relieving the burden on reviewers). However, these recommendations hardly ever focus on the submitting researcher. In the last decade, the number and diversity of research funding calls has increased, as has the total amount of time and resources spent by researchers on funding-related activities (Alberts et al., 2014; Ioannidis, 2011; Gross and Bergstrom, 2019; Link et al. 2008). This development and the general increase in competition between researchers and institutions for funds has forced research groups to create teams and personnel who specialize in competitive funding calls (Etzkowitz, 2003; Höylä et al., 2016; Van Den Besselaar et al., 2012).

We wondered whether the inefficiency induced by so many research groups spending time and resources applying for funding may overcome the potential benefits. In many calls, dozens of research groups apply, but only a couple of them are funded. For example, the funding rate of the US National Science Foundation was around one-third over the last two years (see https://dellweb.bfa.nsf.gov/awdfr3/default.asp). The success rate of the National Institutes of Health's Research Project Grants applications was around one-fifth between 2016 and 2019 (see https://nexus.od.nih.gov/all/2020/05/05/extramural-investments-in-research-fy-2019-by-the-numbers). This situation raises important questions among researchers and decision-makers/policymakers as to whether the existing mechanisms of funding science and research are efficient (Alberts et al., 2014; Bornmann, 2011; Fang and Casadevall, 2016). A growing number of funding institutions and researchers supports the (partial) use of random mechanisms in the allocation of research funding (Avin, 2018; Fang and Casadevall, 2016; Gross and Bergstrom, 2019; Roumbanis, 2019; Vaesen and Katzav, 2017). Low funding rates also involve the danger of increasing unfairness in the selection process, since there is the risk of non-scientific criteria being used to decide between equally qualified applications.

This paper attempts to address possible inefficiency in research funding. We try to identify ways of reducing inefficiency and the waste of time and resources spent on research funding calls. We build on the work of Gross and Bergstrom (2019) and try to identify ways that may reduce inefficiency in the research fund-seeking process.

In order to achieve this objective, we built a theoretical model of research, funding and competition. In this model, research groups allocate efforts between funding and core research activities in order to maximize their research output. The model captures the recursive nature of research activities. The competition for funding is modelled as a Tullock contest, in which greater efforts are associated with higher chances of success (Corchón, 2007; Konrad, 2009). We identify four mechanisms in which decision-makers/policymakers may act in order to reduce possible inefficiencies in the research funding process:

First, by favouring some research groups over the others. For instance, based on certain objective criteria, the decision-makers/policymakers may prefer or give advantage to a particular research group in a call.[1] We will demonstrate that inefficiency decreases when the most productive research groups are favoured over the less productive groups, because their opportunity cost of funding activities in terms of core research activities is higher. The disadvantageous research group has greater difficulty in succeeding, which leads to a reduction in the aggregate effort, competition, and associated inefficiency.

[1] We would like to note that favoring some research groups over others based on objective criteria is difficult: whatever criteria are decided on as being necessary for achieving funding will be gamed and ceased to become their original measure (Goodhart's law). Similar difficulties are found to accurately define which groups are active in a specific topic area.

Second, by restricting the call to a small number of research groups intensively involved in the topic of the call. We will show that decision-makers/policymakers can reduce inefficiency by designing calls directed to research groups that are active in the topic area of the call. If high complementarity, synergy or linkage between funding and core research activities exist, efforts directed at core research activities transform, at low cost, into efforts directed at funding activities and vice versa, which reduces the waste of time and resources.

Third, by reducing the dependence of the funding allocation process on the funding activities effort. We will demonstrate that when the funding process becomes less influenced by the effort spent on funding activities, this effort is reduced. The exogeneity or independence of the funding process on the effort spent on funding-seeking activities could be the strongest instrument in terms of effect and flexibility, and the one that is more likely to be consensual and receive acceptance under very general circumstances (Liu et al., 2020).

This observation might be in line with the idea of random allocation of research funds, which – for some researchers – seems fairer, less biased and more supportive of breakthrough research (see Bornmann, 2011; Bornmann and Daniel, 2005; Luukkonen, 2012). Other researchers refuse pure randomization as it may be incompatible with scientific principles that do not see randomness as a serious solution to real problems (Philipps, 2021). Researchers who take an intermediate position accept randomness providing that certain conditions are met, such as merit or some other quality thresholds, and if the amounts are small and target riskier research (Liu et al., 2020).[2]

Fourth, by reducing the number of research groups competing in a call. We will show that decreasing the number of research groups competing in a call reduces inefficiency of the funding process. On the one hand, the individual effort of each research group in funding activities increase, because the returns and the likelihood of success from fund seeking activities increases. On the other, the aggregate effort decreases because of the direct reduction in the number of research groups. Altogether, the second effect is stronger, and leads to a decrease in inefficiency. Asymmetries between research groups may give rise to some exceptions.

This paper is novel not only in its approach, but also in its objectives. It tries to overcome the polarised debate on competitive versus random allocation of funds to look at alternative allocation mechanisms that might exist between the two possibilities (Ioannidis, 2011; Liu et al., 2020). In particular, the study aims to answer the question how the competitive allocation of research funds could be made more efficient.

The rest of the paper is organized as follows: section 2 presents the model and notation, section 3 presents the results and analyses, and section 4 concludes.

2. Model and Notation

In the following, we present a model in which several research groups $i = 1, \ldots, n$ compete for research funding. There are m_1 research groups of type 1 and m_2 research groups of type 2, where $m_1 + m_2 = n$ is the total number of research groups.

Each research group is endowed with the total amount of resources t_i (e.g. time, researchers, infrastructures, etc.), which represents effort units that can be allocated either for funding activities x_i

[2] A Bayesian ranking approach is proposed by Heyard et al. (2021).

(e.g. preparing research proposals, competing for grants, filling bureaucratic forms, etc.) or to core research activities y_i (e.g. time spend in the lab for actual research activities), where $y_i = t_i - x_i$.

If the research group i proposal is funded, it obtains reward v_i. However, the competitive process is subject to some randomness and it is not even. For instance, some research groups may have advantages over others because they are more experienced, have a better reputation or have superior technology. Consequently, everything being equal, advantageous research groups have more chances of being funded. In this context, let $a_i > 0$ denote the research group i advantage/disadvantage. If $a_i > a_k$, research group i has an advantage over research group k, and the opposite otherwise. If $a_i = a_k$, none of these research group has an advantage or disadvantage over the other.

Therefore, in a competitive process, the likelihood or probability that the proposal of research group i is funded depends (positively) on the effort provided by the research group i, but negatively on the effort provided by the other research groups. The Tullock rent-seeking contest success function is a natural approach to capture this process:

$$p_i = \frac{a_i\left(x_i + s_i^y y_i\right) + c}{\sum_{k=1}^{n}\left(a_k\left(x_k + s_k^y y_k\right) + c\right)}, \tag{1}$$

for $i = 1, \dots, n$. This expression implies that more effort spent on funding activities implies higher winning prospects and that funding is uncertain. With probability p_i research group's i proposal is funded and with probability $1 - p_i$ research group's i proposal is not funded.

The parameter c denotes the degree of randomness of the funding process. For instance, if $c = 0$ the funding process depends exclusively on the time or resources spend on funding activities. If $c \to \infty$ the funding process is completely random, and the time or resources spend on funding activities are irrelevant. In this case, $p_i \to 1/n$ and each of the n research groups have the same chance of obtaining funding independently of their efforts. The introduction of this parameter in the contest success function is important because it makes it possible to study how the effort spent on funding activities varies with c in a meaningful and tractable way. [3]

The parameter $s_i^y \in (0,1)$ is the share of effort spent by research group i in core research activities that can be used to increase the likelihood of group i to obtain funding. In other words, it is the share of effort made by research group i in core research activities that can be transformed into funding activity efforts at no cost. It is natural to expect that stronger groups in terms of research are also stronger in funding activities.

The core research activities return the output $r_i y_i$, where r_i is the marginal return of effort in core research activities and determines the productivity of each research group. Research groups with high r_i are more productive than research groups with low r_i.

Similarly, not all effort spent on funding activities is wasted. A share $s_i^x \in (0,1)$ of this effort can be used or integrated in core research activities. For instance, a research group may not obtain funding, but the time used for writing the proposal is not fully "wasted", as it can be used for other research, learning or even to enter in a new topic in an efficient manner. In this case, the associated research output is given by $r_i s_i^x x_i$.

[3] Recent data from the NIH shows that the signal to noise ratio may be low, meaning that c is high, and the system is behaving like a lottery (Forscher et al., 2019).

Since research is a circular process in which successful funding is constantly required to support subsequent research, research group's i reward v_i is a continuation payoff that depends on the past and present funding successes and efforts. The payoff function of research group i is summarized by the following recursion:

$$v_i = p_i v_i + r_i(y_i + s_i^x x_i),$$

for $i = 1, \dots, n$, where p_i is given by expression (1). Since $y_i = t_i - x_i$, this expression captures the trade-off between effort spent on core research and funding activities in a simple way. After some algebra (i.e. solving for v_i), this expression gives:

$$v_i = \frac{r_i(t_i - (1 - s_i^x)x_i)}{1 - p_i}, \tag{2}$$

for $i = 1, \dots, n$, where p_i is given by expression (1).

Hence, each research group i distributes its effort between funding activities x_i and research activities y_i to maximize the payoff v_i. By choosing x_i, research group i is also choosing y_i because of the relation $y_i = t_i - x_i$ for $i = 1, \dots, n$. Consequently, it is enough to maximise with respect to x_i.

Note the bidirectional feedback between activities. On the one hand, the parameter s_i^x is the share of efforts spent on funding activities that can be applied in core research activities. For instance, a research group may not obtain funding, but the time used for writing the proposal is not fully "wasted". The time can be used for other research, learning or even to start research on a new topic in an efficient manner. On the other hand, the parameter s_i^y is the share of effort spent on core research activities that improve the chances of obtaining funding. Funding and research activities are linked in this way.

In this study, we are interested in analysing the total amount of effort spent by all research groups competing for funding. This aggregated amount measures the inefficiency of the research funding process. In this context, the efforts spent by all research groups in funding activities are given by:

$$X = \sum_{k=1}^{n} (r_k(1 - s_k^x)x_k).$$

The total research output is given by:

$$Y = \sum_{k=1}^{n} (r_k(y_k + s_k^x x_k)) = \sum_{k=1}^{n} (r_k t_k) - X,$$

where higher research output is associated with a more efficient use of available research resources. Since an increase in inefficiency implies a decrease in efficiency (and vice versa), it is enough to focus on one direction. In this study, we focus on X (inefficiency) which depends on the amount of effort spent on funding activities.

3. Analysis and Results

In this section, we study the potential inefficiency induced by applying for research funding and how it varies with the key model parameters. We assume that the parameters are associated with potential inefficiency reduction decisions, policies and objectives.

In order to achieve this objective (without loss of generality) let:

$$s_i^x = s_i^y = s,$$

for $i = 1, \dots, n$. Thus, feedback between funding and core research activities is of the same magnitude. In other words, the share of effort spent on funding activities that is recovered in research activities is of the same magnitude as the effort spent on research activities that is recovered in funding activities for all research groups.

Moreover, let all research groups have the same endowment of resources, i.e., $t_i = t$ for $i = 1, \dots, n$. There is no loss of generality associated with this assumption, because a larger endowment of resources is equivalent to an advantage which is already captured by parameter a_i.

After replacing the contest success function (1) into (2), and maximizing with respect to x_i, where $y_i = t - x_i$ for $i = 1, \dots, n$, we obtain a system of n first order conditions, from which m_1 are research groups of type 1 and m_2 are research groups of type 2.

With some abuse of notation, we drop the index $i = 1, \dots, n$ and use the index $j = 1,2$ to denote the effort provided by each research group of type j.[4] In the case of differences between research groups types, let type 1 be the advantageous or most productive research group type. Therefore, after solving this system for x_j, we obtain the following Nash equilibrium solution in terms of effort by each type.

Proposition 1. *In equilibrium, each research group of type $j = 1,2$ provides the effort level:*

$$x_j^* = \frac{a_j(1 + m_{-j} - 2s)t - a_{-j}(m_{-j} + 2s)t - 2c}{a_j(1 + m_j + m_{-j})(1 - s)}, \tag{3}$$

in funding activities, and $y_j^* = t - x_j^*$ in research activities.[5]

In order to obtain meaningful results, the effort provided by each research group must be non-negative, which is the case when the numerator of expression (3) is non-negative, i.e., when: i) there are no great differences between research groups (small difference between a_j and a_{-j}), ii) feedback, complementarity or linkage between activities is small (small s), and iii) the funding process is competitive and depends mostly on effort (small c). The following results satisfy this condition.

Note that in order to obtain zero effort spent on funding activities it is appropriate to set c sufficiently high, but finite, i.e., there is no need to let $c \to \infty$. In other words, it is enough to partly remove competitiveness in the funding process for inefficiency to be reduced because research groups spend less effort spent on funding activities.

The level of inefficiency induced by funding activities is given as follows.

[4] In order to complete the proof of Proposition 1, we apply symmetry to all groups of type 1 and to all groups of type 2. In this way, we obtain a more manageable system with only two different equations, for which the solution is given by expression (3).

[5] Even in the most general framework, without $s_i^x = s_i^y = s$ and $t_i = t$, expression (3) in Proposition 1 could be obtained in close form. Nonetheless, these assumptions are helpful so that results and analyses are more intuitive.

Proposition 2. *In equilibrium, the research funding inefficiency is:*[6]

$$X^* = \sum_{j=1}^{2} m_j r_j \frac{a_j(1 + m_{-j} - 2s)t - a_{-j}(m_{-j} + 2s)t - 2c}{a_j(1 + m_j + m_{-j})}. \qquad (4)$$

In order to study the effect of the parameters a_j and a_{-j}, m_j and m_{-j}, s and c on effort and inefficiency (which are related with the four policy/decision instruments analysed in this paper), we link a_j with a_{-j}. The advantage of one research group type is the disadvantage of the other type. We define $a_1 = a \in [1/2,1)$ and $a_2 = 1 - a$. If $a > 1/2$, research groups of type 1 have an advantage over research groups of type 2 in obtaining funding. In the case of $a = 1/2$, no research group type would have an advantage over the other.

3.1. Advantages and Disadvantages in the Funding Process

Some research groups may have advantages over others because they are more experienced, have a better reputation, or have superior technology. Consequently, advantageous research groups have better chances of being funded (everything being equal for the rest). We know that this type of heterogeneity between research groups exists. It may be possible that policymakers/decision-makers favour some research groups over others for some justified reasons in order to reduce the level of inefficiency associated with funding activities.

Proposition 3. *In equilibrium, the research funding inefficiency decreases if* $a^2/(r_1((m_2 + 2s)t - 2c)) \geq (1 - a)^2/(r_2((m_1 + 2s)t - 2c))$ *and* a *increases (and vice versa).*[7]

This result reveals that inefficiency decreases when the most productive research groups are favoured because their opportunity costs of funding activities (in terms of core research activities) are higher. The advantage should be higher, the more productive type 1 research groups are relative to type 2 groups, or the higher the number of unfavoured type 2 research groups relative to type 1.

Consequently, policymakers/decision-makers should favour the most productive research groups over less productive groups. For instance, if $r_1 = r_2$ and $m_1 = m_2$ inefficiency decreases if a moves above ½. More generally, if $r_1 > r_2$ and $m_1 = m_2$ inefficiency decreases if decision makers let a much above ½, i.e., when $a \geq \sqrt{r_1}/(\sqrt{r_1} + \sqrt{r_2}) > 1/2$.

Intuitively, the result in Proposition 3 is supported by a "given up" effect that reduces effort spent by disadvantageous research groups on funding activities. Disadvantaged research groups may find it too difficult to compete with advantageous groups and for that reason, they may make less effort. Simultaneously, advantageous groups may rest on their competitive advantage and their effort in the area of funding activities.

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[6] The proof of Proposition 2 is obtained by replacing expression (3) in expression X, for $j = 1,2$, as defined in chapter 2.

[7] The proof of Proposition 3 is obtained by differentiating expression (4) with respect to a and verify the sign of the respective derivative.

To summarize, the higher the difference (similarity) between research groups, the lower (higher) the competition for funding, and the lower (higher) the joint effort and funding inefficiency. This policy objective implies, however, the establishment of an elite of favoured research groups that are the subject of positive discrimination. Such a policy might be the target of criticism and resistance by those who are not funded.

3.2. Complementarity between Activities

The complementarity, synergy or linkage between funding and core research activities is captured by the parameter s. The parameter represents not only the share of effort spent on funding activities that can be used in core research activities, but also the share of effort spent on core research activities that indirectly improves the chances of successful funding. The following result describes the effect of complementarities on the level of inefficiency.

Proposition 4. *In equilibrium, the research funding inefficiency decreases when s increases, and vice versa.*[8]

This result implies that the inefficiency of the funding process falls the higher the complementarities between funding and research activities are. Such a decrease seems a reasonable result, because larger complementarities between activities imply less waste of resources.

However, decision-makers/policymakers have only limited control over the degree of complementarity, which makes it difficult to use it as a policy instrument. Nonetheless, decision/policy makers can reduce the inefficiency by designing calls in which participating research groups have a high value of s. In other words, participating research groups should be highly involved and strongly connected with the subject of a call. In this case, the complementarities are more likely to be high and the funding processes less inefficient because the effort spent on core research activities transform (at low cost) into effort spent on funding activities, and vice versa.

The way to achieve this objective is to restrict the call to a small number of research groups that are highly involved and strongly connected with the subject of the call. This practice is already applied in some calls, which are open to specific groups (with similar level) in order not to motivate external research groups to submit proposals. The practice may be criticized for its exclusivity and for not all research groups have the same opportunities to submit. Nonetheless, our results show that it can be effective.

3.3. Competitiveness of the Funding Process

Competitiveness of the funding process is captured by parameter c. For instance, if $c = 0$ the funding process is extremely competitive. It depends exclusively on resources spent by competing research groups on funding activities. However, when c increases, the funding process becomes less influenced by effort spent by other research groups and less competitive. In the limit, the funding process

[8] The proof of Proposition 4 is obtained by differentiating expression (4) with respect to s and verifies the sign of the respective derivative.

becomes independent of effort spent on funding activities. Consequently, decision makers can manipulate this variable in order to reduce inefficiency.

Proposition 5. *In equilibrium, research funding inefficiency decreases when c increases, and vice versa.*[9]

The result in Proposition 5 follows from the fact that the efforts by both research group types in funding activities decrease when c increases. Decision-makers can reduce inefficiency by making the funding process less competitive and independent from effort spent on funding activities.

An increase in c can be interpreted either as randomness of the funding distribution or as equal distribution of funds among all research groups. Note that the contest success function in Expression (1) can also be interpreted as the share in the total, instead of being interpreted as the probability of winning the total. In either case, the funding process is independent of the research groups' effort spent on funding activities. The randomness or exogeneity of the funding process may seem awkward from a policy/decision perspective. Nonetheless, it might be the strongest available instrument in terms of effect, flexibility, and ability to reach a consensus.[10]

The result in Proposition 5 corroborates the view of several authors who suggest the introduction of random funding mechanisms. These mechanisms are less competitive and independent of the effort spent on funding activities (Avin, 2018; Fang and Casadevall, 2016; Gross and Bergstrom, 2019; Ioannidis, 2011; Roumbanis, 2019; Vaesen and Katzav, 2017). The result confirms the view of many researchers who reject pure randomization (Philipps, 2021). According to Liu et al. (2020), pure randomness is well accepted providing that it is weighted by merit or some other quality threshold measures, or when the amounts involved are small and target the riskier research.

3.4. Number of Research Groups

The number of research groups competing in a funding call is a crucial aspect in terms of aggregate inefficiency. Consequently, we shall take a more detailed look at this variable below.

In order to reduce the level of inefficiency, the decision-maker/policymaker can restrict the number of participating research groups by designing calls that narrow or expand the number of participants according to this objective. The total number of research groups is captured by the parameter $n = m_1 + m_2$, while the number of research groups of each type $j = 1,2$ is captured by the parameter m_j.

Let us start by considering the symmetric case in which all research groups are equal, i.e., $a_j = a_{-j}$ and $r_j = r_{-j}$. In this case, there is only one research group type. We obtained the following result.

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[9] The proof of Proposition 5 is obtained by differentiating expression (4) with respect to c and verifies the sign of the respective derivative.

[10] For instance, the instrument discussed in Section 3.1., which is based on favouring one research group over the other with the objective of reducing inefficiency, may have difficulties in obtaining generalised support. The instrument discussed in Section 3.2., which is based on the degree of complementarities between activities, may be difficult to implement. It requires specific information and may be subject to criticism.

Proposition 6. *In equilibrium, the research funding inefficiency decreases when n $(m_1 + m_2)$ decreases, and vice versa.*[11]

The message in Proposition 6 is clear: the lower the number of research groups competing in the same call, the lower the inefficiency. This result is particularly robust and true even if the research groups have different productivities in core research activities, i.e., if $r_j \neq r_{-j}$.

Intuitively, a large number of research groups increases competition by adding one more group but might reduce individual groups' effort spent on funding seeking activities. At the same time, a large number of research groups increases the aggregate efforts (and consequently the inefficiency), because of the additional group efforts. In other words, the effort inefficiency added by an additional research group is larger than the reduction in efforts by all other groups due to the increase in competition effects.

The following result distinguishes whether the increase in the number of research groups is on the most productive groups (with high r_j) or on the less productive groups (with low r_j).

Proposition 7. *In equilibrium, the research funding inefficiency decreases when m_j increases, if $r_{-j}m_{-j} \geq r_j(1 + m_{-j})$, and vice versa.*[12]

In general, research funding inefficiency increases when the number of research groups increase as it is stated in Proposition 6. Therefore, we must expect the inequality in Proposition 7 to not be satisfied. However, Proposition 7 also states that in some exceptional cases, if $r_1 > r_2$, i.e., type 1 research groups are more productive than type 2 research groups, the competition effect may decrease aggregate inefficiency. However, this may happen only if the increase in the number of research groups is on the less productive research groups (type 2). Simultaneously, $r_1 m_1 \geq r_2(1 + m_1)$, i.e., the most productive research groups have a sufficiently strong advantage. Otherwise, the inequality in Proposition 7 would not be satisfied.

In other words, in the asymmetric case, increasing the number of research groups may not necessarily increase inefficiency (as in the symmetric case of Proposition 6), if the decision/policy maker selectively increases the number of less productive research groups and at the same time, the most productive research groups have a sufficiently strong advantage. In this case, the competition increasing effect is stronger than the inefficiency induced by an additional research group. We speculate that the level of inefficiency may then decrease.

However, this scenario may be an exception. In general, we can expect the inequality in Proposition 7 to not be satisfied and Proposition 7 equals Proposition 6. An increased number of research groups increases inefficiency and waste of resources – independent of research groups' type. It follows that decision/policy makers should design calls that are restricted to a small number of participants. In line with the results obtained in the previous section, these results show that decision-

[11] The proof of Proposition 6 is obtained by imposing symmetry and differentiating expression (4) with respect to n, and then verifying the sign of the respective derivative.
[12] The proof of Proposition 7 is obtained by differentiating expression (4) with respect to m_j and verify the sign of the respective derivative.

makers/policymakers should restrict and narrow the subject and the requirements of the calls as much as possible.

6. Conclusions and Discussion

This paper studies possible inefficiencies of research funding processes in terms of generating useless effort spent on fund-seeking activities and discusses ways of reducing or mitigating this effort. We identify four mechanisms in which policymakers/decision-makers may act to reduce the inefficiency of the research funding process:

1) Inefficiency decreases when the most productive research groups are favoured over the less productive groups, in part because of the "given up" effect of disadvantageous research groups and the decrease in competition. 2) Inefficiency decreases if research calls are designed for (few) research groups that are closely connected to the subject of the call. In this case, the effort spent on core research activities transforms, at low cost, into effort spent on funding activities, and vice-versa, which reduces potential losses. 3) Inefficiency decreases when the funding process becomes less dependent on the amount of effort spent on funding activities. This result might support the random (or deterministic, in the sense of equal distribution) allocation of research funding that several authors in the literature favour (Avin, 2018; Fang and Casadevall, 2016; Gross and Bergstrom, 2019; Ioannidis, 2011; Liu et al., 2020; Philipps, 2021; Roumbanis, 2019; Vaesen and Katzav, 2017). 4) Inefficiency decreases when the number of research groups competing in the same call is small because it decreases the number of research groups spending effort spent on fund-seeking activities.

The four approaches of reducing inefficiency may be not equally powerful; neither do they share the same simplicity in terms of implementation. It might be effective in some cases to reduce the dependence of the funding process on the efforts spent on fund-seeking activities (Proposition 5) or to reduce the number of research groups (Propositions 6 and 7) by narrowing the subject of the call to research groups that are strongly related to the subject (Proposition 4). However, these activities might be sensitive issues. For instance, restrictions in the number or the type of research groups can be subject to criticism regarding discrimination (positive or negative), equal opportunities and fair competition. Despite those difficulties, and controlling for the emergence of a "Matthew effect" in science funding (Bol et al., 2018) and diminishing returns (Fortin and Currie, 2013), it might be particularly effective to separate research groups into ranks (based on their past results) in order to target the participant groups as much as possible and reduce inefficiency. For instance, it might be more efficient to have four research groups divided into two calls, with two research groups in each call according to some narrowing criteria, rather than one single call with all four research groups competing against each other. Decision-makers/policymakers may consider such issues when designing research calls; otherwise, there is the risk that induced inefficiency by having many research groups applying for funding overcomes potential benefits. Some calls are likely to distract researchers from their core activities. This problem has become increasingly recognised among researchers (Adam, 2019; Fang and Casadevall, 2016; Gross and Bergstrom, 2019; Ioannidis, 2011; among others).[13]

[13] In this context, it is logical for researchers to spend a large amount of time applying for funding. However, this may lead to (1) inefficiency as excessive time is spent on proposal writing and (2) a "spiraling competition" for funds (Geard and Noble, 2010). Altogether, reducing competition can be the key to reduce inefficiency. This idea is also supported by Barnett et al. (2015). The decrease of the prestige of research funding could be also an effective way to reduce inefficiency, because some of the competition to win funding is spurred by the prestige it gives to the researchers and their university. However, it is not clear how this can be done as it may distort other incentives.

If funding agencies try to reduce inefficiency, it is important to guarantee that the pursuit of the inefficiency reduction objective does not create different inefficiencies or injustices in the funding process. For that reason, we are reluctant to recommend the use of fully random mechanisms. For instance, Liu et al. (2020) found in a recent survey of New Zealand researchers the following: most applicants reported that the lottery did not change the time they spent for preparing their application. So, the efficiency savings of using a lottery may be smaller than expected.[14] Instead, in our view, funding mechanisms should be competitive, but specific and targeted in order to reduce the effort spent on fund-seeking activities that add no (or only marginal) value to the core research objectives and activities of the applicants.

Note, however, that targeted research calls can also have problems. For instance, the involved researchers may act very optimistically and submit ineligible or not sufficiently working applications. Having an expression of interest could reduce this issue, but it increases overall costs and may slow the decision process. Targeted calls can also (1) degenerate or subsume into the status quo which they initially intended to fix or (2) create unhealthy competition between groups who could otherwise be good collaborators. Moreover, targeted calls put a lot of influence in the people who create the targets. For instance, in Australia targeted calls for medical research funding have become highly political (Gilbert et al., 2021).[15] There is also the risk that some researchers are willing to bend the rules to win funding and that some research groups may become efficient at winning funding, but less efficient at doing research.

Several extensions or variations of the original model proposed here are possible. For instance, alternative models for studying research calls could follow a detailed cost/benefit analysis (Tuffaha et al., 2016) considering the time spend/lost in the process (Bisias et al., 2012). This paper mostly looks at inefficiency reduction. However, as pointed out by Hackett and Chubin (2003) there are efficiency-effectiveness trade-offs. For instance, the proposed mechanisms may also result in lower diversity and innovation. It may block the entrance of new emerging research groups into the research field, among other problems. Altogether the problem should be seen holistically, and further research should look at those trade-offs. The contest success function in this paper already adds a layer of uncertainty, as funding is not always guaranteed. However, other types of uncertainty and variation between research groups are also possible extensions.

Heterogeneity between research groups may also play an important role in the study of research funding inefficiencies. Extensions of the original model could take differences between research groups into account. The original model distinguishes teams in terms of the available resources, and in terms of productivity (two levels: high and low). These levels may be useful in model calculations, but in practice it may be problematic to set the boundaries of a research team (who is in and who not - and this may be strategically presented by the team), to measure the output of the team (which has various dimensions), and even more difficult, to measure productivity (output per person). A team could be a professor with a few PhD students and postdocs, a few professors with all kind of other (research and teaching) staff, or a strategic combination created to address a specific call.

It might be difficult to empirically measure the output and productivity of a research team, or even to define and measure abstract concepts like the “boundaries of the research team” or “how close a research team is to a research topic”. Nonetheless, several authors have proposed strategies to

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[14] Nonetheless, as pointed out by Avin (2018) the gains to science by random funding could be surprisingly large: thanks to giving funding to truly ground-breaking ideas that are often not funded by usual funding systems.

[15] Rachel Clun (10/12/2020). The Sydney Morning Herald. Australian medical research funding doesn't pass governance test: Chris Bowen. URL: https://www.smh.com.au/politics/federal/australian-medical-research-funding-doesn-t-pass-governance-test-chris-bowen-20201209-p56lzy.html

measure research output and productivity within teams or even attempted to define the concept of "discipline" or "field". The studies of these authors might be the starting point to empirically measure qualitative concepts associated with research teams (Abramo and D'Angelo, 2014; Porter et al., 2006; Rey-Rocha et al., 2002; Schmoch et al., 2010; Stokols et al., 2008; Wagner et al., 2011; among others).

One of the objectives of this paper is to call readers' attention to this under-studied and important issue and to encourage research on funding inefficiency. We hope that our findings will help researchers and decision-makers/policymakers to better understand the existence of inefficiencies in research funding processes and to design financing schemes that can reduce and mitigate inefficiencies.

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