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Funder Restrictions on Application Numbers Lead to Chaos

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Abstract

Restricting application rates is an attractive way for funders to reduce time and money wasted evaluating uncompetitive applications. However, mathematical models show that this could induce chaotic cycles in total application numbers, increasing uncertainty in the funding process. One emergent property is that smaller institutions spend disproportionally more time unfunded.

Funders are under pressure to reduce numbers of grant applications

Increasing the efficiency of resource allocation is a significant priority for funders and research organisations. Time and effort spent writing, processing and reviewing unsuccessful applications is largely wasted, since, in contrast with the publications process in which most rejected papers are eventually published, rejected grants are usually never funded. As success rates are often only 10% or even lower, and rarely as high as 30%, the resources lost to unsuccessful applications are considerable.

Low success rates are undoubtedly not in the interests of research funders, researchers or universities and research institutes. Funders have led the responses to this, primarily by introducing systems to restrict the numbers of applications that they receive. Individuals, or institutions, with poor success rates are subject to application limits, notionally encouraging them to increase application quality. Based on an analysis of the trade-off between success and effort, a target success rate of 20% is thought to be optimal [1].

Investigating the effects of application caps

One such system (termed *demand management*) was recently introduced by the UK's Natural Environment Research Council (NERC) in response to long-term declines in its success rates. Institutions that are unsuccessful (average success rate of <20%) over the medium term (3 years) are penalised by capping the maximum number of applications they are permitted to submit. The intention is to achieve a success rate of 20% overall[i]. The specific rules for this system are included in the supplementary text (Models of NERC demand management).

From a mathematical perspective, the grant application process can be regarded as a discrete-time dynamical system. When control measures are introduced in such systems, for example by introducing application caps, is known to induce chaotic behaviour [2, 3]. Indeed, we find such behaviour in deterministic and stochastic models of the NERC demand management system (see supplemental text, Models of NERC demand management). Figure 1 shows the behaviour of an ensemble of institutions chosen to reflect key characteristics of the distribution of applications typically received by NERC (see supplemental data file, NERC_DATA.csv[ii]).

The deterministic system (Figure 1a) displays extreme 4-year cycles with a positive Lyapunov exponent (estimated numerically, see Wolf and colleagues [4]), a characteristic of chaotic behaviour. The attractor from which these chaotic cycles arise is shown in Figure 1c. While this cyclic behaviour becomes much less pronounced in the stochastic system (Figure 1b), it remains statistically detectable demonstrating that the underlying dynamics remain the same in both models. Thus, these models show that, even if chance is removed from the grant award process, the application dynamics arising from the demand management system will remain inherently unpredictable.

Under these conditions, the success rate achieved does not reach the target of 20%. This is because uncapped institutions are permitted to submit as many applications as they wish. Moreover, at the level of an individual institution we find that the dynamics of the system exhibit scale dependence (Figure 2). There are qualitative differences for small, medium and large-sized institutions in the likelihood of being subject to, and the effect of, demand management (Figure 2a – c). Institutions subject to the minimum cap are likely to spend a protracted period in this state. For this reason, smaller institutions, which have an application capacity closer to this minimum, are more likely to be subject to demand management than larger ones (Figures 2d & e). The only exception to this is when success rates are very low. Moreover, as shown in Figure 2f, in demand management the success rate of small institutions drops substantially, while those of medium and large institutions are almost unaffected.

Implications for funders, research institutions, and individual researchers

Our analysis highlights three key features of systems which impose limits on application numbers:

(i) Such limits can impose disproportionate disadvantages on specific subgroups of the academic community. In this specific case, organisations face a significant potential handicap if they are small or medium sized even though their applications are of the same quality as those of larger institutions.

(ii) Specific target success rates cannot be attained simply by limiting applications from individuals or institutions with low success rates. Instead interventions which encourage all applicants to modify their behaviour are required. In particular, unless all institutions take steps to reduce the numbers of applications they submit, NERC demand management will generate significant variability in application numbers (and thus success rates).

(iii) Reducing the number of applications made is the only way to attain long-term target success rates. Increasing the quality of applications is insufficient, since if all applications were to improve it would still be impossible to fund them all, thus the only outcome would be an increase in unfunded excellence.

Unfortunately, declining success rates across funders suggest that there is a much greater pool of applicants than there is financial resource to support them [5-7]. In the very long-term that means two, non-exclusive, outcomes. We emphasise that these are an inevitable consequence of limited funds, but restrictions on applications will potentially create additional stresses. First, many groups will be unfunded for long periods and this will lead to a slow degradation in outputs and capability in the absence of other funding. As we argue above, this is particularly likely to apply to groups within small and medium sized institutions. Second, universities and research institutions may become wary of investing strategic support into areas supported by funding bodies which introduce such restrictions, if applications to them are regarded as risky. This would lead to a reduction in capability, particularly in small and medium sized institutions, exaggerating the existing inequalities in the system [8].

The final issue to raise is that, when applications are restricted on the institutional level, the most important strategic imperative for an institution subject to such restrictions is to increase success rates. In the long-term this is for the benefit of the whole institution as it will permit all researchers to submit grants when they wish. However the best short-term mechanism for achieving this is obviously to only submit grants which are deemed to have the highest chance of success. This strategy of 'backing winners' runs a risk of disadvantaging junior staff in favour of established stars thus exacerbating the existing demographic biases (e.g. age, sex and race) present within academia. Additionally, the most innovative proposals, which have the greatest transformative potential, may be discouraged as they are typically more risky than incremental projects building on existing work. These effects are potentially difficult to measure. For example, NERC reports that there has been no fall in awards to new investigators since demand management was introduced[i]. However, they note that applications from new investigators have decreased substantially and that, according to feedback from institutions, new investigator status has been considered when determining which applications to submit.

Are application caps the best solution to the problem?

Although the bottom line is that in a resource limited world we cannot support everything, we believe that our analysis reveals that there are possible unintended consequences of application caps that will impact on both individual researchers and the whole research field. Our model suggests that some of these negative effects might be mitigated by small changes to the systems used. For example, increasing the minimum application cap from one grant to two in the demand management system (see supplemental figure S1) substantially increases the success rates of small institutions in demand management although they still spend more time in this state. Similarly, the potential bias against newer staff might be mitigated by not counting applications from such staff against the institutional cap, although we note that our model does not specifically address this issue.

Imposing individual sanctions on applications, whether on institutions or individuals, is likely to induce periodic variation in the overall number of applications received; as cycles of low application pressure allow restrictions to be lifted with a subsequent spike in application numbers. Introducing a cap on the total number of applications would address this variability, but, if application opportunities are allocated on the basis of past success, runs the risk of creating a positive feedback loop favouring the creation of a single dominant institution.

Of course, imposing restrictions is not the only way to address the inefficiencies of the funding process. The radical reimagining proposed by Bollen and colleagues [5], combining a universal basic research income with researcher-led redistribution of funds, would eliminate the grant application process, and thus its inherent waste, completely. However, there is little evidence that funders are seriously considering this approach as yet [6]. More practically, the National Science Foundation has achieved a reduction in application numbers in some of its schemes by relaxing, rather than increasing, restrictions on grant applications [7]. By moving to a continuous funding model, eliminating grant application deadlines, their scheme appears to reduce pressure to submit an application at every opportunity and to encourage applicants to spend more time refining their proposals. Given the inherent limitations of attempting to restrict application numbers that we have demonstrated, we suggest that funders should consider more permissive, rather than restrictive, approaches to application management.

Resources

[i] http://www.nerc.ac.uk/funding/available/researchgrants/demand/dm-review2015-17/

[ii] http://www.nerc.ac.uk/funding/application/outcomes/success/

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Figure 1: Demand management results in chaotic grant application cycles. Typical trajectories of overall application numbers are plotted for (**a**) deterministic and (**b**) stochastic

models of the grant application and award process. The mean number of applications per annum, their standard deviation, and the overall success rate are given for each model. These trajectories display a characteristic four year cycle, the Lyapunov exponent of which was estimated for the trajectory arising from the deterministic model. The attractor for this cycle is visualised (**c**) in terms of the frequency of orbits through a particular volume of phase space. This attractor divides into two states, high application cycles and low application cycles, of different frequencies (see inset labels).

Figure 2: The effect of demand management varies disproportionately with institution size. Typical application dynamics, arising from the stochastic model, are plotted for each of the three institution sizes: (**a**) large, $\lambda = 100$; (**b**) medium, $\lambda = 50$; and (**c**) small, $\lambda = 10$. Years in which an institution is subject to demand management (DM) are indicated by a red circle. Three summary measures of the effect of demand management: (**d**) the time spent in demand management; (**e**) the length of a period in demand management; and (**f**) the success rate of an institution dependent on its demand management state, were calculated for three overall success rates, see legend. Overall success rate was controlled by decreasing the application rate for each institution size by a common factor. Note that the length of periods in demand management are approximately exponentially distributed, and that, as such, the mean is used to summarise these distributions.

Figure_1

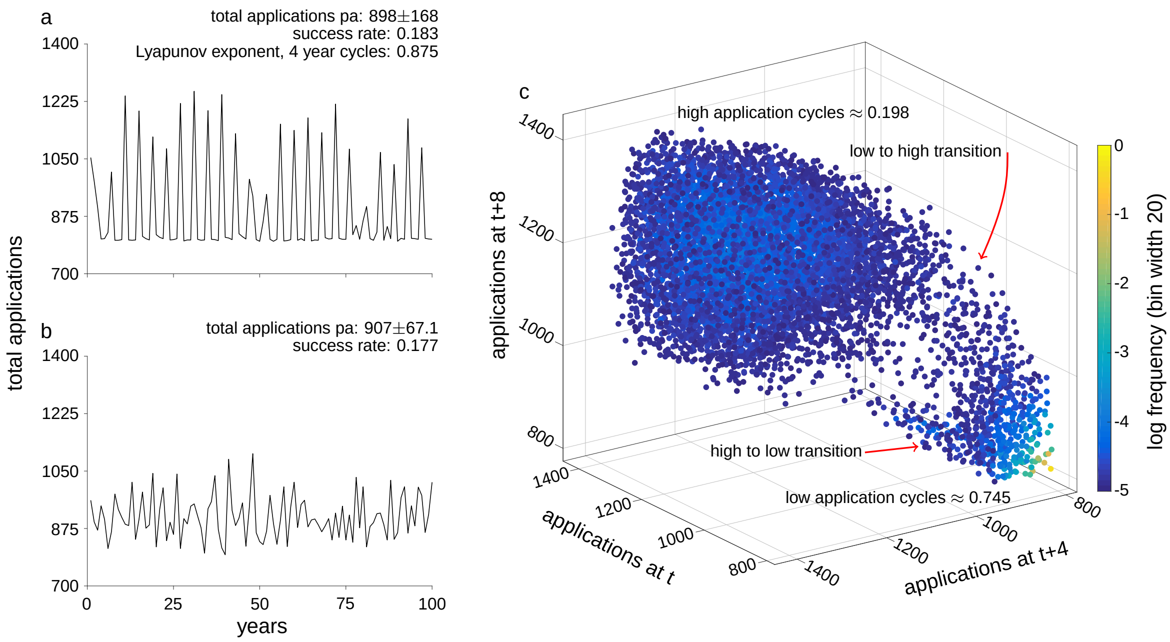
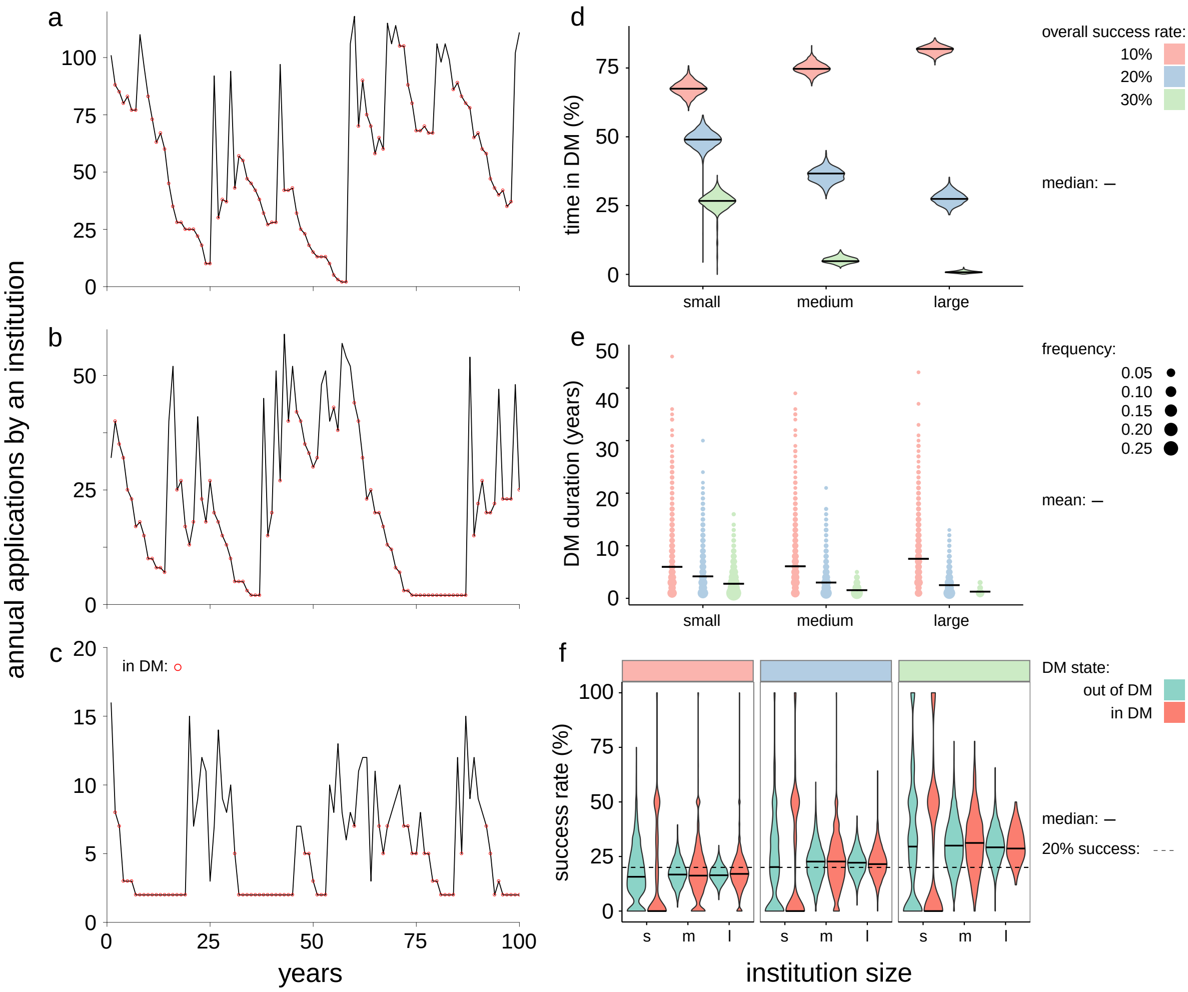

a
total applications pa: 898±168
success rate: 0.183
Lyapunov exponent, 4 year cycles: 0.875
b
total applications pa: 907±67.1
success rate: 0.177
total applications
years
c
high application cycles ≈ 0.198
low to high transition
high to low transition
low application cycles ≈ 0.745
applications at t+8
applications at t
applications at t+4
log frequency (bin width 20)

Figure_2



a
b
c
d
e
f
annual applications by an institution
in DM:
years
time in DM (%)
small
medium
large
overall success rate:
10%
20%
30%
median: –
DM duration (years)
frequency:
0.05
0.10
0.15
0.20
0.25
mean: –
success rate (%)
DM state:
out of DM
in DM
median: –
20% success: - - -
s
m
l
institution size