Localized Prosocial Preferences, Public Goods and Common-Pool Resources

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The presence of prosocial preferences is thought to reduce significantly the difficulty of solving societal collective action problems such as providing public goods (or reducing public bads). However, prosociality is often limited to members of an in-group. We present a general theoretical model where society is split into subgroups and people care more about the welfare of others in their own subgroup than they do about out-groups. Individual contributions to the public good spill over and benefit members in each group to different degrees. We then consider special cases of our general model under which we can examine the consequences of localized prosociality for the economic outcomes of society as a whole. We ask to what extent prosociality closes the welfare gap between the Nash equilibrium without prosociality and the social optimum. The answer depends on whether private and public inputs are good or poor substitutes in producing final output. Critically, the degree to which this welfare gap closes is a concave function of the level of prosociality in the case of poor substitutes, so even low levels of prosociality can lead to social welfare near the social optimum.

public goods| game theory | local prosociality| common-pool resources | collective action

As the world becomes more interconnected, we increasingly are faced with problems of the Commons and their governance (1–3). Individuals and nations withdraw water, fish and other resources from a finite pool, overuse of antibiotics erodes their effectiveness (4), and the emission of pollutants and greenhouse gases fouls the atmosphere. In most such situations, individual incentives are insufficient to restrain usage of finite resources and sustain public goods in the Commons; governments must find ways to change the incentive structure to overcome the tendency to overexploit when bottom-up processes are inadequate (5). The task may be easier in smaller societies, where prosocial preferences may play a greater role. In this paper, we examine how prosociality may make action in the collective good easier, and how incentives can reinforce prosociality to achieve collective benefits.

Prosocial preferences and other-regarding behaviors more generally are a fact of life, though it is often puzzling how they are sustained (6–10). In a related paper we examine one pathway, where each generation educates the next to instill prosocial preferences (11). In this paper, we beg the question of why prosociality exists, but rather ask what its consequences are for achieving cooperation.

The main issue on which we focus in this paper is particularly relevant to public goods or bads that affect large and widespread populations; maintenance of order and regulation in trade, commerce and financial markets (goods), high-seas fisheries overexploitation, emissions of greenhouse gases and some other pollutants (bads), are examples with worldwide reach. However, it is evident from public policy debates that prosociality does not extend worldwide. Individuals care more about their immediate circles of family and friends than they do for the general public in their region or state, more for their local population than for the national citizenry at large, and more for their fellow-citizens than for foreigners.

In this paper, we ask to what extent localized prosociality can help solve collective action problems that have wider or even global scope. We construct a general theoretical framework to structure how such problems can be modeled, and analyze a simple theoretical model that is consistent with this general framework and gives some answers about when limited prosociality leads to the greatest increase in public-goods investments and social welfare. Finally, we discuss possible applications of our model and offer ideas for future research.

We find that the elasticity of substitution of public and private effort is a key predictor of whether modest levels of prosociality lead to high levels of public-goods provision. For public goods with limited private substitutes, such as climate change mitigation, our models predict that prosociality can be effective in leading to increased public-good contributions. On the other hand, if good private substitutes exist, then our results suggest that modest levels of prosociality are unlikely to lead to sufficient public-good supply. Climate-change adaptation is such a case. As a concrete example, adaptations to increased flood risk in coastal regions can take many forms, ranging from natural landscape changes that mute the impact of storm surges (12), to elevating individual homes. The former is a public good with benefits that accrue at the community scale, while the latter is a private substitute. In this case, our models predict that prosociality is alone unlikely to lead to high contributions to natural landscape protections,

Significance Statement

Prosocial preferences and other-regarding behaviors more generally are a fact of life. Yet, the degree to which these preferences can play a role in resolving problems of the Commons is not well understood. We develop a framework for modeling the impact of prosociality on public goods provision and social welfare when individuals care more about members of their own group than members of other groups. We find that prosociality is most effective at moving individuals toward optimal public goods provision when there is low substitutability between the public good and its private alternatives. This finding sheds light on systems in which prosociality can be an effective mechanism for the resolution of public goods problems.

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even if this is the socially optimal response to the increased risk of storm surges as sea levels rise.

A general prosociality framework

Here we lay out a model of public-good provision with prosocial preferences, building on Dixit (13). There are n individuals, labeled $i = 1, 2, ..., n$; each individual belongs to one of m groups where the subscript $k_i \in \{1, ..., m\}$ denotes group membership of each individual. Each can exert two types of effort: private x_{ik_i}, and public z_{ik_i}. The public good may consist of the effort itself, for example volunteered time, or it may be a good or service produced one-for-one using aggregate public effort; either interpretation works equally well. We assume the public good increases the productivity of private effort; for example, better roads make private transport more efficient, and better education increases private skills and therefore raises the productivity of individual labor*. We assume this effect is channeled through a function

$$Z_j = g_j(z_{1k_1}, z_{2k_2}, ..., z_{nk_n}) \quad [1]$$

where the public-good level in group j, Z_j, is non-decreasing in each individuals public-good contribution. Further, the functional form of g may be different for each group, to account for the structure of public-good spillovers and varying degrees of congestion in the production and consumption of the public good. At one extreme, the public-good level in group j, Z_j, could simply be the sum of the z_{ik_i}'s, implying that there is no congestion, and the public good is global. Alternatively, complete congestion of a local public good would imply that Z_j is the mean of the z_{ij}'s, so that, first, average investment in the public good is what matters (due to congestion); and, second, the public-good level for members of group j is produced only by its own members (there are no public-good spillovers). This general framework also allows for consideration of intermediate cases. A high degree of congestion of public goods makes them more closely resemble common-pool resources, where the use by one person precludes its use by others. With our framework, individual i's income, when a member of group j, is given by

$$y_{ij} = f(x_{ij}, Z_j) \quad [2]$$

where f is a function of private input, x_{ij}, and the level of the public good in group j, Z_j. We assume that levels of the public good impact the productivity of private investment, and that f is increasing in both x and Z. This income is transformed into utility via a function that incorporates prosociality, and the cost of investment in public and private goods. This can be expressed generally as

$$U_{ij} = h_j(y_{1k_1}, ..., y_{nk_n}, x_{ij}, z_{ij}) \quad [3]$$

where h is non-decreasing in each $y_{1k_1}, ..., y_{nk_n}$, but non-increasing in x_{ij} and z_{ij} so that investment is costly. The functional form of h depends on group membership so that own-group outcomes can be more highly weighted than the outcome of other groups. Choosing particular formulations for the costs of investment and benefits of output allows us to assess the circumstances under which prosociality has the greatest potential to lead to high public-goods contributions. Further, the generality of this framework gives it the flexibility to be tailored to a large array of societally relevant public-goods problems.

*Conversely, public bads such as pollution and congestion lower private productivity; this is a mirror-image case of our model and can be analyzed similarly.

Fixed Budget Model

For the remainder of the paper, we consider a special case of our general framework where each individual has a fixed budget that can be invested in public or private effort. We model income as a function of private effort and the local level of the public good, with constant elasticity of substitution between the public good and private effort. Prosociality is modeled as the weight that individuals put on the payoff of others within and outside their group.

Model. There are two groups, labeled 1 and 2, with n_1 and n_2 members respectively.† Each member i of group g has a given total "budget" B_g (which could be money or time), and chooses the allocation of spending between private use x_{ig} and z_{ig}, so

$$x_{ig} + z_{ig} = B_g. \quad [4]$$

Each unit of the public spending by a member of group 1 generates λ_{11} units of its own public good and λ_{12} units of group 2's public good, and similarly the other way round. So the total quantity of the public good of group 1 is

$$Z_1 = \lambda_{11} \sum_{i=1}^{n_1} z_{i1} + \lambda_{21} \sum_{k=1}^{n_2} z_{k2} \quad [5]$$

and similarly for Z_2. It is not necessary to have the own λ greater than the cross; we could be talking about a public bad, like air or water pollution, that is carried primarily to the other group.

The income of individuals depends on their private spending and the public good available to them with possible congestion.

The function defining income y_{ig} for person i in group g is

$$y_{ig} = \left[\alpha \, (x_{ig})^\rho + \beta \, \left(\frac{Z_g}{(n_g)^\theta} \right)^\rho \right]^{1/\rho}. \quad [6]$$

This function is a member of the "constant elasticity of substitution" family, which has been widely used, since its introduction in economics by (14), for highlighting varying possibilities of substitution between inputs. We need $\rho \leq 1$ and the elasticity of substitution between private and public inputs is $\sigma = 1/(1-\rho)$. If $\rho = 1$, we see from (6) each iso-y_{ig} locus in (x_{ig}, Z_g) space is a straight line. Therefore the two inputs are perfect substitutes (not necessarily one-for-one) along it, so $\sigma = \infty$. As $\rho \to -\infty$, the substitution possibility goes to zero and the inputs are required in fixed proportions. The Cobb-Douglas function used in many models of economic growth (for a restatement and overview see (15)) corresponds to $\rho = 0$. Finally, θ, which should be non-negative, captures congestion effects on the public good. $\theta = 0$ is the no-congestion case, and as θ increases, the efficacy of a fixed amount of public good decreases as population size increases.

The utility (objective function) of person i in group 1 is

$$U_{i1} = y_{i1} + \gamma_{11} \sum_{j \neq i,\, j=1}^{n_1} y_{j1} + \gamma_{12} \sum_{k=1}^{n_2} y_{k2} \quad [7]$$

and similarly for members of group 2. The γs are prosociality parameters toward members of the own and the other group. We assume that $1 > \gamma_{11} > \gamma_{12} \geq 0$ so that individuals care more about themselves than others in their group and more

†The only additional difficulties in generalization to more groups are notational complexity.

about members of their own group than members of the other group.

It is easy to verify that the objective function is (weakly) concave in the choice variables x_{ig} and z_{ig}, and the constraint is linear, so first-order conditions are sufficient for utility maximization. Assume for the moment that all the x's and z's are positive in the solution. This implies that the first-order condition for person i in group 1 is[‡]

$$\frac{\partial U_{i1}}{\partial x_{i1}} = \frac{\partial U_{i1}}{\partial z_{i1}}. \qquad [8]$$

Note that x_{i1} affects U_{i1} only through y_{i1}, but z_{i1} affects it through its effect on Z_1 and Z_2 which affect all the y_{jg}. Therefore we can write (8) as

$$\frac{\partial y_{i1}}{\partial x_{i1}} = \left[\frac{\partial y_{i1}}{\partial Z_1} + \gamma_{11} \sum_{j\neq i, j=1}^{n_1} \frac{\partial y_{j1}}{\partial Z_1}\right] \lambda_{11} + \gamma_{12} \sum_{k=1}^{n_2} \frac{\partial y_{k2}}{\partial Z_2} \lambda_{12}. \qquad [9]$$

Further, since everyone within a group is identical, we can let $x_{ig} = x_g$ for all i, and similarly for the other variables. This allows us to write our first order conditions for members of group 1 as

$$\begin{aligned} Z_1 &= \lambda_{11}\, n_1\, z_1 + \lambda_{21}\, n_2\, z_2 && [10] \\ y_1 &= \left[\alpha\, (x_1)^{\rho} + \beta \left(\frac{Z_1}{(n_1)^{\theta}} \right)^{\rho} \right]^{1/\rho} && [11] \\ \alpha\, (x_1)^{\rho-1}\, (y_1)^{1-\rho} &= \beta\, \lambda_{11}\, (n_1)^{-\theta\rho}\, (Z_1)^{\rho-1} && [12] \\ & \quad [1 + (n_1 - 1)\, \gamma_{11}]\, (y_1)^{1-\rho} \\ & \quad + \beta \lambda_{12} n_2 \gamma_{12} (n_2)^{-\theta\rho} (Z_2)^{\rho-1} (y_2)^{1-\rho} \end{aligned}$$

with three similar equations holding for group 2 (see SI Appendix, section (A) for a complete derivation). We have eight equations – these six plus the two budget equations from (4) – for the eight variables x_1, x_2, y_1, y_2, z_1, z_2, Z_1 and Z_2.

Next, we consider some special cases that permit simple analytical and numerical solutions to yield more detailed insights and intuition.

Localized prosociality. First, we consider the case prosociality only extends to members of ones own group. Thus $\gamma_{12} = \gamma_{21} = 0$, and equation (12) simplifies to[§]

$$\alpha\, (x_1)^{\rho-1} = \beta\, \lambda_{11}\, (n_1)^{-\theta\rho}\, (Z_1)^{\rho-1}\, [1 + (n_1 - 1)\, \gamma_{11}]$$

or

$$x_1 = K_1\, Z_1$$

where

$$K_1 = \left\{ \frac{\beta}{\alpha}\, \lambda_{11}\, (n_1)^{-\theta\rho}\, [1 + (n_1 - 1)\, \gamma_{11}] \right\}^{1/(\rho-1)}. \qquad [13]$$

Taking into account the budget constraint, this results in a simple linear equation system with the solution (for a complete analysis, see SI Appendix, section (B))

$$\begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} 1 + K_2\lambda_{22}n_2 & -K_1\lambda_{21}n_2 \\ -K_2\lambda_{12}n_1 & 1 + K_1\lambda_{11}n_1 \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} \qquad [14]$$

where

$$\Delta = (1 + K_1\lambda_{11}n_1)(1 + K_2\lambda_{22}n_2) - (K_1\lambda_{21}n_2)(K_2\lambda_{12}n_1). \qquad [15]$$

We need $\Delta > 0$ for this equilibrium to be locally stable if dynamics are of the form $\frac{dz}{dt} \propto \frac{\partial U}{\partial z}$ (see SI Appendix, section (B.1)).

The solution will have positive z_1 and z_2 so long as the two groups' parameters, and especially their budgets B_1 and B_2, are not too asymmetric. If B_2 is very large compared to B_1, for example, (14) can yield $z_1 < 0$; then we will have to set z_1 equal to zero and recalculate the rest from the other first-order conditions. This results because when group 2 has a very large budget, it willingly expends so much of it on the public good that members of group 1 find it optimal to concentrate all their effort on private investment. This feature of free-riding by small groups is well-known in other contexts such as military alliances; see (16).

Symmetric prosociality. In this case we consider two identical groups with symmetric in-group and cross-group prosociality and spillovers. This allows us to omit group subscripts because each group is the same. Further, since each group will make the same equilibrium investment decision, we can write $x_1 = x_2 = x$ and $z_1 = z_2 = z$. Also let $\lambda_{11} = \lambda_{22} = \lambda_o$ and $\lambda_{12} = \lambda_{21} = \lambda_c$ [¶], and similarly for the γs. Then (12) simplifies to

$$\alpha\, x^{\rho-1} = \beta\, \{ \lambda_o\, [1 + (n-1)\, \gamma_o] + \lambda_c\, n\, \gamma_c \}\, n^{-\theta\rho}\, Z^{\rho-1}$$

which can be written as

$$x = H\, Z$$

where

$$H = \left[\frac{\beta}{\alpha} n^{-\theta\rho} \{ \lambda_o [1 + (n-1)\gamma_o] + \lambda_c n \gamma_c \} \right]^{1/(\rho-1)}. \qquad [16]$$

Also, (5) becomes

$$Z = (\lambda_o + \lambda_c)\, n\, z.$$

Then

$$B = x + z = H\, Z + z = [1 + H\, (\lambda_o + \lambda_c)\, n]\, z$$

giving the solution

$$z = \frac{B}{1 + H\, (\lambda_o + \lambda_c)\, n}. \qquad [17]$$

This implies that

$$Z = \frac{(\lambda_o + \lambda_c)\, n\, B}{1 + H\, (\lambda_o + \lambda_c)\, n},$$

$$x = \frac{(\lambda_o + \lambda_c)\, n\, H\, B}{1 + H\, (\lambda_o + \lambda_c)\, n}$$

and

$$\begin{aligned} y &= \left[\alpha\, (HZ)^{\rho} + \beta\, Z^{\rho}\, n^{-\theta\rho} \right]^{1/\rho} \\ &= \left[\alpha\, H^{\rho} + \beta\, n^{-\theta\rho} \right]^{1/\rho}\, Z \\ &= \left[\alpha\, H^{\rho} + \beta\, n^{-\theta\rho} \right]^{1/\rho}\, \frac{(\lambda_o + \lambda_c)\, n\, B}{1 + H\, (\lambda_o + \lambda_c)\, n}. \end{aligned}$$

[‡] In economics jargon, the "marginal utilities" of the two types of efforts should be equalized. Mathematically, the common value of the derivatives in (8) equals the Lagrange multiplier on the budget constraint, but we don't need that.

[§] A similar simplification results if instead there are no cross-group spillovers ($\lambda_{12} = \lambda_{21} = 0$), but this seems a less realistic and also less interesting case.

[¶] Subscript o stands for own, c for cross.

The criterion for judging social welfare is the sum of everyone's income,

$$W = 2\,n\,y$$

and we can judge the effect of prosociality as the fraction of the welfare gap, from no prosociality to full prosociality, that is closed by intermediate levels of prosociality. Substituting y into our measure of social welfare, we can write

$$W = \frac{\left[\ \alpha\ H^{\rho} + \beta\ n^{-\theta\rho}\ \right]^{1/\rho}}{1 + H\,(\lambda_o + \lambda_c)\,n}\,(\lambda_o + \lambda_c)\,n\ B \qquad [18]$$

but note that only H changes as a function of the levels of prosociality, so we will focus our analysis on H, and ignore multiplicative factors in W that are unchanging. Consider three situations:

First, no prosociality: Here $\gamma_o = \gamma_c = 0$, and the resulting value of H is

$$H_0 = \left[\ \frac{\beta}{\alpha}\ n^{-\theta\rho}\ \lambda_o \right]^{1/(\rho-1)}. \qquad [19]$$

Write the resulting social welfare as W_0.

Next, full prosociality: Here $\gamma_o = \gamma_c = 1$, and the resulting value of H is

$$H_1 = \left[\ \frac{\beta}{\alpha}\ n^{1-\theta\rho}\ \{\,\lambda_o + \lambda_c\,\} \right]^{1/(\rho-1)}. \qquad [20]$$

Write the corresponding value of social welfare as W_1.

Finally, consider the intermediate case with arbitrary given $\gamma_0,\ \gamma_c\ \in (0,1)$. Here the general expressions for H and W, (16) and (18), apply.

Now we define the beneficial effect of prosociality as the fraction ϕ of the gap between W_0 and W_1 that is achieved by $\gamma_0,\ \gamma_c\ \in (0,1)$, that is

$$\phi = \frac{W - W_0}{W_1 - W_0}.$$

In figure 1 we show how ϕ depends on prosociality. We find that as the elasticity of substitution, σ, of public goods and private effort decreases, a fixed level of prosociality has greater benefits. When $\gamma_o = \gamma_c = R$, the expression for the general H, (16) can be simplified and yields

$$\begin{aligned} H^{\rho-1} &= \frac{\beta}{\alpha}\ n^{-\theta\rho}\ \{\lambda_o\ [1 + (n-1)\,\gamma_o] + \lambda_c\,n\,\gamma_c\} \\ &= \frac{\beta}{\alpha}\ n^{-\theta\rho}\ \{\lambda_o\ [1 + (n-1)\,R] + \lambda_c\,n\,R\ \} \\ &= (1-R)\ \frac{\beta}{\alpha}\ n^{-\theta\rho}\ \lambda_o + R\ \frac{\beta}{\alpha}\ n^{1-\theta\rho}\,(\lambda_o + \lambda_c) \\ &= (1-R)\ H_0^{\rho-1} + R\ H_1^{\rho-1} \end{aligned}$$

using (19) and (20). As R goes from 0 to 1, H goes from H_0 to H_1, and thus W goes from W_0 to W_1. Then ϕ can be expressed as a function of R and other unchanging parameters. This case is highlighted in figure 2, and shows that σ is a critical determinant of how rapidly the welfare gap closes even when within-group and cross-group prosociality are equal.

Figure 3 shows contours of constant ϕ in a unit square in the (γ_o, γ_c). The level curves are linear, because as we see from (16), these two prosociality levels affect welfare only as a weighted sum, $\lambda_o\,(n-1)\,\gamma_o + \lambda_c\,n\,\gamma_c$. Note that the level curves are linear regardless of the value of σ (corresponding to $\rho = 1 - (1/\sigma)$).

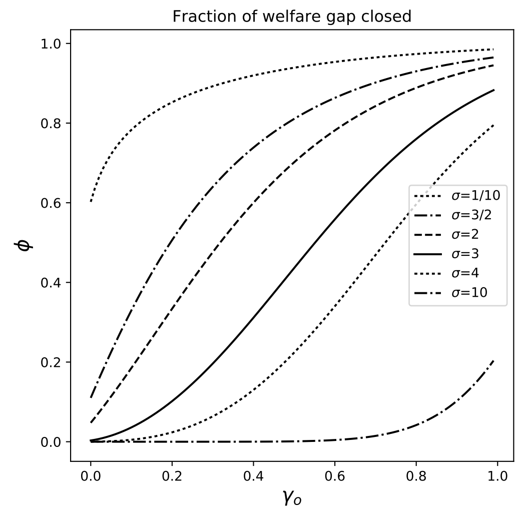

Fig. 1. The fraction of the welfare gap closed, ϕ, as a function of in-group prosociality, γ_o, for a range of elasticities of substitution, σ, with cross-group prosociality fixed at $\gamma_c = .05$. For low elasticities of substitution, the fixed level of cross-group prosociality is sufficient to significantly close the welfare gap, and increases in in-group prosiciality further improve the social outcome. For high levels of substitutability (e.g. $\sigma = 10$) even high levels of in-group prosociality cannot lead to an outcome that approaches the social optimum. $\alpha = 1/2, \beta = 3, \theta = 4/3, \lambda_o = 1, \lambda_c = 8/10, n = 750, B = 60$.

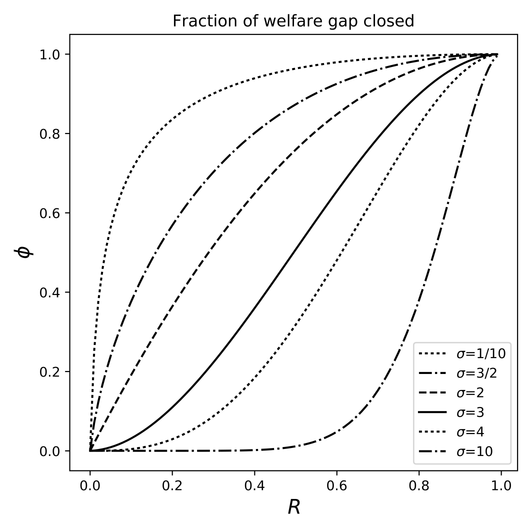

Fig. 2. The fraction of the welfare gap closed, ϕ, as a function of $R = \gamma_o = \gamma_c$ for a range of elasticities of substitution, σ. For low elasticities of substitution, even low levels of prosociality can lead to a significant reduction in the welfare gap between the selfish Nash outcome and the social optimum. Under full prosociality, $R = 1$, the social optimum is attained regardless of the value of σ. $\alpha = 1, \beta = 1, \theta = 3/2, \lambda_o = 1, \lambda_c = 1/2, n = 100, B = 100$.

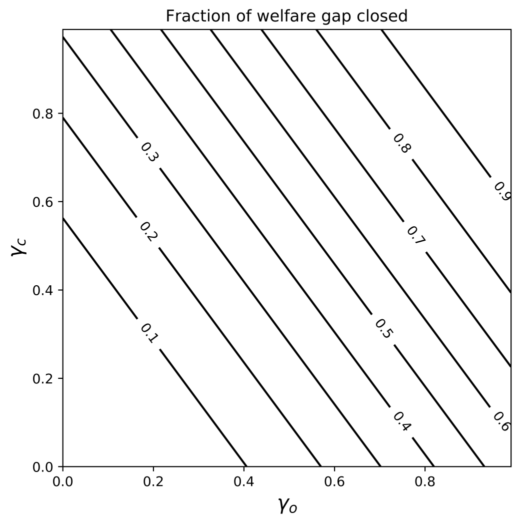

Fig. 3. The level curves of ϕ, the fraction of the welfare gap closed by intermediate levels of prosociality, as a function of in-group and cross-group prosociality. The level curves are linear with the relative importance of γ_o and γ_c for social welfare dependent on the structure of public good spillovers. $\alpha = 6/10, \beta = 8/10, \theta = 3/2, \lambda_o = 7/10, \lambda_c = 1/2, \sigma = 10/3, n = 100, B = 100.$

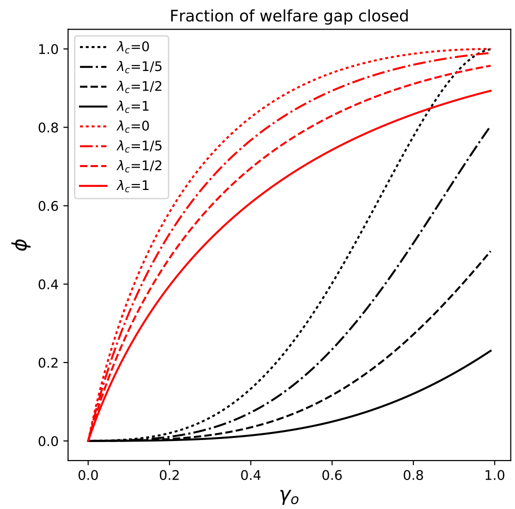

Fig. 4. The fraction of the welfare gap that is closed as a function on in-group prosociality, γ_o, for low substitutability in red($\sigma = 1.1$) and high substitutability in black($\sigma = 5$). Curves are shown for four different levels of cross-group public-good spillovers. This shows that the propensity of public goods to spill over has a large impact on ϕ for public goods with high substitutability, especially under high in-group prosociality. If substitutability is low, then cross-group spillovers have a small effect on social welfare across all levels of in-group prosociality, γ_o. $\alpha = 1, \beta = 8/10, \theta = 6/5, \lambda_o = 1, \gamma_c = 1/100, n = 12, B = 10.$

Figure 4 shows how the closure of the welfare gap depends on the propensity of public goods to spill over and on the degree of in-group prosociality. The red curves are for the case of low substitutability of the public good with private investment. In this case, the degree of spillovers, λ_c, has a modest effect on ϕ, the fraction of the welfare gap closed. Black curves are for public goods with high degrees of substitutability. Here we see that when in-group prosociality is high, ϕ depends strongly the degree of spillovers. This highlights the context dependence of our predictions about the efficacy of prosociality to resolve public-goods problems. For public goods with low substitutability of private alternatives, in-group prosociality can lead to outcomes near the global optimum even when the public good has high spillovers to other groups. On the other hand, when a public good has high substitutability with private alternatives, in-group prosociality can lead to an outcome with welfare near the social optimum only when public-good spillovers are very low.

Discussion

The models we present advance the theory of prosociality and public goods where there are spillovers of public goods and private substitutes to public goods. Our general framework, and our specific insights, are relevant to many of the pressing problems of the Commons that societies face. In table 1, we present possible case studies that span a spectrum of elasticities of substitution and spillover structures.

For example, investment in improved air quality is a public good that can have high spillovers from one jurisdiction to another; however, particulate matter pollution, in particular, is often quite local. The nature of the pollutant, and its propensity to disperse will impact the likelihood of limited prosociality being sufficient to mitigate the damages from the pollution. Further, the elasticity of substitution between private approaches to dealing with air pollution, such as individuals wearing face masks to reduce exposure to pollution, and public approaches, such as limiting emissions, greatly impacts the degree to which our model predicts even small amounts of prosociality will lead to high levels of public-good investment to limit air pollution.

Action on climate change can take two forms, either mitigation of emissions to limit the magnitude of change to the climate, or adaptation to the changes that occur. While emissions mitigation is inherently a public good, climate adaptation can be public or private in nature. For example, individuals in coastal areas can elevate their homes to protect themselves from sea-level rise and accompanying storm surges, or communities can invest in public infrastructure, such a levee, that benefits the whole community. These public and private actions have a high degree of substitutability and thus our model predicts that prosociality is unlikely to lead to high investment in levees when households can opt for raising their homes as an alternative. Thus, if levees are the socially optimal response to sea level rise in a community, implementation will likely need to rely on public funding and not voluntary contributions.

We modeled the provision of public goods resulting from prosocial preferences within and across groups. We incorporated spillovers of the public good across groups, allowed for varying degrees of congestion of the public good, and varying levels of substitutability of public goods and private effort in the income function. We incorporated these features into a general framework that allows for the analysis of many public-goods and common-pool resource problems. Then we analyzed a special case of our general framework, when (1) there is a constant elasticity of substitution between public and private effort, and (2) each individual has a fixed budget that can be invested in either public or private goods. We found that if the elasticity of substitution between public and private goods is low, then relative public-goods contributions are concave in the degree of prosociality, and even low levels of prosociality can support public-goods provision that in near to the social

Table 1. Possible applications for our model across degrees of substitutability of public and private goods and levels of spillovers of the public good

	Public Goods	
Spillovers or Substitutability	Low Spillovers	High Spillovers
Low Substitutability	National Defense Public Education	Water use Climate Change (mitigation)
High Substitutability	PM Pollution Public Transit	Climate Change (adaptation) Air Quality

optimum. On the other hand, when the elasticity of substitution is high, nearly complete prosociality is needed to achieve an outcome where welfare is near the social optimum.

In future work, we will consider a related model where each individual's total investment (private plus public) is variable, with increasing marginal costs of investment, and where the level of the public good increases the rate of return to private investment. This formulation is also consistent with the general framework presented in this paper. A key feature of our modeling is its focus on the relationships among public-good spillovers, substitutability of public and private efforts and the possibility for prosociality to lead to an outcome that is near the social optimal. Our analysis fits within a general framework of prosociality and public goods that has the flexibility to apply across many of problems of the Commons, from local to global scales.

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