From Local Adaptation to Global Mitigation: How Improving Food Security by Building Local Resilience Can Help Limit Climate Change

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ABSTRACT

Climate change poses significant challenges to food security. Traditional climate policies have focused primarily on global mitigation efforts, emphasizing the reduction of carbon emissions. However, these strategies often encounter collective action problems and fall short of achieving their targets. This Article explores how local adaptation projects, which aim to enhance resilience to climate change, can also contribute to global mitigation efforts. By incorporating a model that evaluates the externalities of local adaptation projects on global mitigation, the study finds that investing in local adaptation not only improves food security but also enhances global mitigation efforts more effectively than direct global interventions. The model suggests that prioritizing local projects with significant mitigation externalities can be a more efficient strategy for donors. This Article provides examples of efficient adaptation techniques, including the use of resilient crops, efficient irrigation technologies, and low global warming potential refrigeration options. These findings advocate for a "glocal" approach, where local solutions are designed with global impacts in mind, thereby addressing the collective action problems at both levels and offering a sustainable path to mitigate climate change's effects on food security.

***Keywords**: Climate change, food security, climate adaptation, climate mitigation, collective action*

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I. INTRODUCTION

Climate change is expected to pose several challenges in the coming decades, especially to food security.[1] The expected disruptions to food security in susceptible regions will likely unfold in two main areas: food availability (supply), which corresponds to how much food can be produced and food access (demand), which determines how easy it is for people to obtain food, irrespective of production levels (e.g., if flooding destroys roads and infrastructure necessary for delivering and storing food).[2] Because both local (e.g., field soil quality, floods, and droughts) and global (e.g., supply chain, changing seasonal patterns) trends can determine the supply and demand of food, effectively addressing the impacts climate change has on food security requires solutions implemented across different levels of resolution: local, regional, and global.

Most policy discussions, at least in developed countries, focus primarily on the global level, heavily emphasizing *mitigation*, namely, "addressing the tragedy of the global commons . . . [primarily] . . . by assigning national level emissions targets, which countries are

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[1] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [IPCC], GLOBAL WARMING OF 1.5 C: AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS, IN THE CONTEXT OF STRENGTHENING THE GLOBAL RESPONSE TO THE THREAT OF CLIMATE CHANGE, SUSTAINABLE DEVELOPMENT, AND EFFORTS TO ERADICATE POVERTY 9, 32 (2018) [hereinafter IPCC Global Warming].

[2] *See* Christopher B. Barrett, *Measuring Food Insecurity*, 327 SCI. 825, 825 (2010); Ore Koren & Benjamin E. Bagozzi, *From Global to Local, Food Insecurity is Associated with Contemporary Armed Conflict*, 8 FOOD SEC. 999, 1000 (2016).

expected to translate into their domestic policies."[3] Key aspects of mitigation include reducing carbon emissions and employing carbon-capturing technologies.[4] To be successful to a degree that allows temperature trends to return to their pre-industrial level course, mitigation-focused solutions require cooperation on a global scale. Every country must regulate its economy to achieve net-zero emission levels.[5] Yet, while governments have put billions of dollars into mitigation efforts, the impacts of these mitigation efforts still fall far short of the target.[6]

Moreover, a key challenge is to ensure States will choose to cooperate to address climate change's global impacts. Collaboration over climate change mitigation is subject to *collective action problems*.[7] Collective action problems refer to a situation where national interests (e.g., achieving development goals, maintaining industrial advantage) discourage joint action, even if the long-term outcome is optimal for all actors involved.[8] In this case, States choose not to cooperate even if cooperation will achieve the best ultimate outcome, which creates the problem.[9]

A different solution for the adverse impacts of climate change on food security availability and access relates to *adaptation*, which "refers to policies, proactive or reactive, that seek to reduce the biophysical, social, and economic vulnerability (or enhance resilience) of a given area, organization, population group, or individuals to climate change."[10] Whereas mitigation works primarily on the national and international levels, adaptation strategies are implemented locally and are designed to provide communities and households with the means to cope with the specific, immediate effects of climate change, including food insecurity.[11] Examples of adaptation measures include, among others, planting more resilient crops, building dams and

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[3] Nives Dolšak & Aseem Prakash, *The Politics of Climate Change Adaptation*, 43 ANN. REV. ENV'T & RES. 317, 318 (2018).

[4] *Id.* at 316.

[5] *See* Nives Dolšak, *Mitigating Global Climate Change: Why are Some Countries More Committed Than Others?*, 29 POL'Y STUD. J. 414, 415 (2001).

[6] *See* IPCC Global Warming, *supra* note 1, at 96.

[7] *See* MANCUR OLSON, THE LOGIC OF COLLECTIVE ACTION: PUBLIC GOODS AND THE THEORY OF GROUPS 6–8 (Harv. Univ. Press 1965).

[8] *See* Elinor Ostrom, *A Polycentric Approach for Coping with Climate Change* 8 (World Bank World Dev. Rev., Working Paper No. 5095, 2009); Robert O. Keohane & David G. Victor, *Cooperation and Discord in Global Climate Policy*, 6 NATURE CLIMATE CHANGE 570, 572 (2016).

[9] For an illustration of some of these problems from a rational choice modeling perspective, *see generally Peter* John Wood, *Climate Change and Game Theory*, 153–170 (CCEP working paper 2.10, 2011).

[10] Labanya Prakash Jena, *Financing India's Climate Adaptation: Need for a Novel Mechanism*, MEDIUM (Aug. 28, 2021), https://medium.com/@labanyaprakashjena/financing-indias-climate-adaptation-need-for-a-novel-mechanism-c6a84738f51 [https://perma.cc/4CBK-GHBE] (archived Aug. 17, 2024).

[11] *See* Dolšak & Prakash, 2018, *supra note* 3, at 327.

granaries, managing environmental resources such as grazing land or water reservoirs, and training locals in more effective sustainable food production.

An important advantage of adaptation over mitigation is in its comparatively lower costs, which create measurable positive impacts.[12] A key disadvantage is that adaptation is often viewed as being "a finger in the dike" solution: where adaptation can provide a temporary solution, only mitigation will provide a permanent one.[13] Moreover, like mitigation, local-level adaptation can also be subject to collective action problems.[14] For instance, some local communities may regularly access food or water, while others do not. In this case, installing a resource-sharing mechanism to facilitate adaptation goes against the incentives of those communities that have regular access. Solving these local-level issues therefore necessitates designing adaptation strategies in a way that can incentivize cooperation over defection.[15]

While addressing collective action problems locally is key to achieving adaptation, another issue that scholars often ignore, and that is our specific focus in this Article, relates to the impact of local adaptation on global mitigation. If the most effective way to achieve a long-term solution to climate change and its impacts is via mitigation, then it makes sense to consider approaches that will ensure adaptation-focused solutions will also have some positive impact on mitigation. In other words, in this Article, we highlight the role of the *externalities* of adaptation projects that focus on improving food production and addressing food and water demand. By "externalities," we refer to the unintended second- and third-order impacts of adaptation not directly related to their immediate impacts on food security, and in our case, as these specifically relate to climate change mitigation. Further, we examine whether, if enough adaptation strategies incorporate mitigation-improving externalities, this incorporation will lead to sufficiently effective mitigation impacts.

To achieve these aims, gain insights on how to solve these issues at the local level, and infer how to maximize global impacts, we developed a simple formal model, adapting it for different local realities. The key insights from our model suggest that improving food security levels via local climate change adaptation efforts that have global externalities is a more effective way, in many cases, not only to solving the local impacts of climate change but also to improving global

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[12] *See* Mia Landauer, Sirkku Juhola & Maria Söderholm, *Inter-relationships Between Adaptation and Mitigation: A Systematic Literature Review* 131, CLIMATIC CHANGE 505, 508–510.

[13] *See generally* David B. Lobell, *Climate Change Adaptation in Crop Production: Beware of Illusions* 3 GLOB. FOOD SEC. 72, 72–76 (2014).

[14] *See* Ostrom, *supra* note 8, at 22.

[15] *See generally* Shardul Agrawala & Maarten Van Aalst, *Adapting Development Cooperation to Adapt to Climate Change* 8 CLIMATE POL'Y 183, 183–193 (2008).

mitigation. Moreover, we find that it is sometimes better to invest in a suboptimal solution that has greater externalities on improving global mitigation than to fund solutions that optimize local adaptation's success but do not have such impacts.

Our model hence suggests that an effective approach to solving the collective action problem surrounding climate change and its potential impacts on food security is to invest effectively in local solutions that maximize global externality impacts over both the short- and the long-term. We offer some specific examples of such adaptation techniques in the last part of this Article.

II. THE MODEL

Imagine a donor (e.g., a State, an international organization, an international nongovernmental organization) with sufficient funds to invest in local adaptation projects. Yet, the donor is also concerned about mitigating climate change globally. Moreover, in addressing the latter, the donor is also facing a daunting global collective action problem.

Thomas Dietz, Elinor Ostrom, & Paul C. Stern offer one approach to solving collective action problems. [16] Focusing on local community action, the authors identify several mechanisms that can facilitate collective action by internalizing the costs of defection, including providing information, dealing effectively with conflict, inducing rule compliance, providing infrastructure, and preparing for a change in structures and incentives.[17] Considering the localized nature of these mechanisms, however, they cannot effectively "scale up," as attempts break down at the national or international level.[18] We have very few examples of successful global environmental cooperation at this scale.[19] One case includes the successful implementation of ozone-healthy policies, which required removing products that use chlorofluorocarbons (CFCs).[20] While this case has been successful, considering that there was little cost of substituting CFCs, it does not really resemble the complex issues underlying climate mitigation.

To this end, Dietz, Ostrom, & Stern also discuss some conditions that allow for such mechanisms to "scale up" to the international level.[21] In particular, they highlight the importance of dialogues involving scientists, resource users, and the public, as well as creating

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[16] *See* Thomas Dietz, Elinor Ostrom & Paul C. Stern, *The Struggle to Govern the Commons*, 302 SCI. 1907, 1908–10 (2003).

[17] *Id.* at 1908–10

[18] *See id.* at 1910.

[19] Elinor Ostrom, *A General Framework for Analyzing Sustainability of Social-ecological Systems* 325 SCIENCE 419, 419–422 (2009).

[20] Christian Sartorius, *Phase-out of CFCs and the Protection of the Ozone Layer* TIME STRATEGIES, INNOVATION, AND ENV'T POL'Y 55 (2005).

[21] *See* Dietz, Ostrom & Stern, *supra* note 16, at 1909–1910.

complex and nested institutional arrangements.[22] These suggestions, however, are vague, and, moreover, what constitutes "an institution" within this framework is also unclear. Elinor Ostrom takes a more disaggregated approach (that is also more in line with the logic we advocate), suggesting that state and municipal governments can help with breaking down global collective action.[23] Yet, in emphasizing mitigation rather than adaptation, Ostrom does not explain why local communities should seek to reduce emissions compared with the benefits of maintaining the status quo.[24] Considering Ostrom's focus on climate change broadly rather than its specific implications, she also does not provide effective solutions to addressing specific local problems that might result locally from climate change, including food insecurity.

Taking these issues and the constraints posed by limited budgeting and collective action problems into account, we construct our model. Here, we emphasize both the importance of adaptation in offering short-term solutions to food insecurity resulting from the local impacts of climate change, and the role of externalities in facilitating mitigation and long-term resilience. In constructing our model, we therefore assume that local food security problems are at least somewhat connected to (i.e., influenced by) global climate change, so that the externalities we hypothesize are feasible.

Consider the following model of collective action:

$$\begin{gathered} u_i(C_i, S) = B - c,\ u_i(D_i, S) = B, \\ u_i(C_i, F) = -c,\ u_i(D_i, F) = 0 \end{gathered} \tag{1}$$

where $B > 0$ is the benefit of collective action and $c > 0$ is the cost of contributing to the collective effort. Thus, $u_i(C_i, S)$ is the payoff that player i obtains when it cooperates and the collective action is successful, while $u_i(D_i, S)$ is the payoff that player i obtains when it does not cooperate and the collective action is successful (i.e., the "freeriding" payoff).[25] $u_i(C_i, F)$ is the payoff that player i obtains when it cooperates and the collective action fails, while $u_i(D_i, F)$ is the payoff that player i obtains when it does not cooperate and the collective action fails. Finally, suppose that the probability that collective action is successful is equal to the proportion of players that cooperate.

It is easy to compute the unique Nash equilibrium of this model, which depends on the number of players N. Formally, if $N \leq \frac{B}{c}$, then everyone cooperates; if $N > \frac{B}{c}$, then everyone defects and nobody

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[22] *See* Dietz, Ostrom & Stern, *supra* note 16, at 1910.

[23] *See* Ostrom, *supra* note 8, at 22.

[24] *See* Ostrom, *supra* note 8, at 16–19.

[25] *See* OLSON, supra note 7, at 23–24.

cooperates (see Proposition 1 in the appendix).[26] In practice, this means that only small groups can successfully advance their common goals, while large groups suffer from "free riding," as people do not contribute knowing they will still enjoy the benefit if collective action succeeds.

Now, consider a situation in which there are several local food security issues resulting from climate change (indexed by l) in addition to the global problem of mitigating climate change (indexed by G). Each of these local issues faces a collective action problem: without any external intervention, there is no cooperation on any issue. Formally, we assume that $N_l > \frac{B_l}{c_l}$ for all l and $N_G > \frac{B_G}{c_G}$, which induces freeriding on these issues.

Imagine that a donor that only cares about implementing mitigation globally has a budget R to subsidize this effort. The subsidy per individual required to induce full cooperation on issue l is $\tau_l = \frac{c_l N_l - B_l}{N_l}$. Thus, it will cost $\tau_l N_l = c_l N_l - B_l$ to the donor to generate full cooperation on issue l. As mentioned above, considering the complexities involved, global mitigation requires significantly more subsidies than any local issue. In other words, the most complicated collective action problem is the global one (G). Formally, this means that freeriding in the case of mitigation is $c_G N_G - B_G > c_l N_l - B_l$, meaning it is bigger than any freeriding problems involving local issues l.

Finally, in this model we also formally define externalities, the second-order effects that are a key aspect of our theory. Here, let $\beta_l \in (0,1)$ be the externality impact of any successful adaptation project (l) on global mitigation efforts. These externalities include (as mentioned above) the possibility that implementing effective adaptation strategies reduces overall emissions in the local community over the long term. Given these externalities, the key question is: What is the optimal allocation of subsidies that the organization should select?

A. *A Simple Case of Adaptation to Climate-induced Food Insecurity*

Let us start with a simple case in which all local adaptation issues are identical; they all address the same concern, face the same freeriding problem, involve the same costs, and have the same externality impact on mitigation (formally, $c_l N_l - B_l = c_L N_L - B_L$ and $\beta_l = \beta_L$ for all issues l). If instead of focusing on local adaptation, the funder focuses on subsidizing collective action for global mitigation, then the amount available for subsidizing local collective action issues will be very small, less (or no) local adaptation projects are

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[26] Technically speaking, for $N = \frac{B}{c}$, players are indifferent between cooperation and defection, but we assume that in this razor edge case they coordinate, and all cooperate.

implemented, and——accordingly——adaptation will produce no externality effects on climate (see Appendix for details). Considering the far more complex collective problem involving global mitigation, in focusing solely on mitigation, the funder is not only unable to promote local resilience but also achieves little in return for their investment.

Alternatively, if the donor chooses not to subsidize global mitigation, they can fund (many) more local food security adaptation programs, thereby not only improving resilience but also enjoying the additive externality impact of these projects on global mitigation (see Appendix for details). Comparing the payoffs, we find that the best donor strategy is to advance global collective action *indirectly* by addressing local collective action issues over adaptation rather than by directly subsidizing global mitigation. In this case, the donor can "eat their cake and have it too"; they can solve local food insecurity challenges resulting from climate change but also have a strong impact on improving mitigation efforts that are even stronger than what can be achieved by directly subsidizing them. Interestingly, this is the case *even if the donor cares little about local adaptation*. As long as the externality impact satisfies the condition stipulated in Equation (2) below, then engaging in mitigation via investing in local adaptation projects provides a better "bang for their buck" even for achieving mitigation.

$$\beta_L > \frac{(c_L N_L - B_L)}{(c_G N_G - B_G)} \frac{B_G}{B_L} \tag{2}$$

B. *A Case of Adaptation Projects with Warying Mitigation Externality Impacts*

What if some climate adaptation projects that can improve local food insecurity locally have different external impacts on climate change mitigation? Naturally, these projects become very attractive for the donor organization. To illustrate this point, consider that there are only two types of local adaptation projects, one with low and the other with high external impacts on mitigation. Denoted by β_L^L (β_L^H) the external effect on mitigation of low (high) impact local adaptation projects. Furthermore, assume that all these projects are equally complicated in the sense that their associated collective action problems require the same subsidy to induce cooperation. Thus, $N_l - c_l N_l - B_l = c_L N_L - B_L$ is the same for all adaptation projects. Provided that $\beta_L^H > \frac{(c_L N_L - B_L)}{(c_G N_G - B_G)} \frac{B_G}{B_L}$, the donor is better if they address mitigation indirectly focusing on subsidizing high-impact local adaptation projects. Moreover, note that this is the case even if low-external impact adaptation projects have a very low external effect on mitigation (formally, if $\beta_L^L < \frac{(c_L N_L - B_L)}{(c_G N_G - B_G)} \frac{B_G}{B_L}$). This suggests that identifying local adaptation projects with high external impact on mitigation and including those alternatives in the menu of options available for donor organizations is crucial for ensuring success. Finally, note that it is possible that local adaptation projects with high-external impact on mitigation will produce lower adaptation benefits. In this case, there is a trade-off between adaptation and mitigation.

C. *A Schelling-Ostrom Model of Collective Action*

One potential problem with the previous collective action model is that, unless the donor provides incentives to internalize freeriding costs, freeriding is rampant. A more reasonable approach to solving this collective action problem is to treat it as if it were a coordination problem. We can rely on the Schelling-Ostrom model of collective action, a more complicated case of Equation (1), to do so:

$$\begin{gathered} u_i(C_i, S) = B - c + s,\ u_i(D_i, S) = B, \\ u_i(C_i, F) = -c,\ u_i(D_i, F) = 0 \end{gathered} \tag{3}$$

where $s > c > 0$. This model is different from Olson's version in that players are happy to contribute *if they know the projects will improve food security*, but not if they expect the project to fail. In other words, in this case, "free riders" are happy to contribute if they know contributing will pay off (i.e., if they can coordinate with others to ensure everyone contributes, then they will solve the freeriding problem). This means that, even for a large group of people, there are several possible equilibrium outcomes, not just defection and freeriding. Importantly, these outcomes include not only a complete success (nobody defects) and a complete failure (everyone defects) but also partial success (only some people defect, or some people cooperate in some cases and defect in others). At first glance, multiple equilibrium outcomes might seem problematic. Fortunately, there are modern techniques that allow us to determine the probability that collective action will succeed for the model in equation (3). This logic is formalized in Proposition 2 in the Appendix and leads to[27]:

$$\alpha = \Pr\ (C_i \text{ for all } i\ ) = \frac{(s-c)N + B}{s(N-1)} \tag{4}$$

Now, consider that global mitigation efforts face an Olsonian type of collective action problem from our general model, but each local food

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[27] *See* LUIS FERNANDO MEDINA, A UNIFIED THEORY OF COLLECTIVE ACTION AND SOCIAL CHANGE 134 (2007) for a formalization of this approach to collective action problems; *see also* María Victoria Anauati, Brian Feld, Sebastian Galiani & Gustavo Torrens, *Collective Action: Experimental Evidence*, 99 GAMES & ECON. BEHAV. 35, 37 (2016) for a laboratory experiment finding supportive evidence for this approach.

security adaptation issue faces a Schelling-Ostrom collective action problem. As Dietz, Ostrom, & Stern show, this is a reasonable assumption given the greater complications of governing global commons (e.g., global mitigation) relative to local commons (e.g., local adaptation).[28]

As before, assume that without any intervention, global mitigation efforts will fail (formally, $N_G > \frac{B_G}{c_G}$). Additionally, without any intervention, the probability that local adaptation issue l will be successful is given by $\alpha_l = \frac{(s_l - c_l)N_l + B_l}{s_l(N_l - 1)} \in (0,1)$, which requires that $N_l > \frac{B_l + s_l}{c_l}$. That is, without intervention, collective action on issue l is not guaranteed to succeed, but neither is complete failure expected. Moreover, the subsidy per individual required to induce full cooperation on local adaptation issue l is $\tau_l = \frac{c_l N_l - s_l - B_l}{N_l}$. Thus, it will cost $c_l N_l - s_l - B_l$ to the donor to generate full cooperation on local adaptation issue l.

Assuming that all local adaptation issues are identical, in the Appendix we show that a donor that is only concerened about expected global mitigation should only fund local adaptation issues if and only if:

$$\beta_L > \frac{s_L(N_L - 1)B_G}{(c_G N_G - B_G)B_L} \tag{5}$$

Comparing equations (2) and (5) (i.e., comparing between solving global mitigation directly and indirectly, respectively), we conclude that the threshold in (5) is easier to reach than the threshold in (2) if (and only if) $s_L < \frac{c_L N_L - B_L}{(N_L - 1)}$. That is, it must be the case that there is some room to improve the probability of advancing local adaptation issues with the donor's support. More intuitively, if local adaptation issues face easier collective action problems (i.e., that coordination is easier to achieve than experiencing rampant freeriding) that can be realistically solved with a limited budget, then it is even better to address global mitigation indirectly by focusing on promoting local climate change adaptation.

D. *Key Model Insights*

To summarize this Part, our model and the different generalizations and equilibrium derivations suggest several insights with respect to adaptation and mitigation policies:

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[28] *See generally* Dietz, Ostrom & Stern *supra* note 16, at 1907, 1909.

(1) Investing in improving food security via local adaptation projects has global implications for improving current and future mitigation goals.

(2) In some/many cases, a more effective way of achieving global mitigation impacts is through local channels, which introduce the notion of mitigation as well as tools to facilitate it into local climate change adaptation projects.

(3) For donors seeking to select across multiple local projects, the most effective investment is in adaptation projects that have the greatest global mitigation externality, *even if these projects do not provide the most efficient local solutions* (i.e., they have asymmetric impacts). As long as some local utility beyond immediate adaptation is achieved (i.e., the local collective action problem is easier to solve than the global one), maximizing global externalities makes sense.

(4) Moreover, as we show above, insight 3 holds true *even if local people are initially unaware* of global climate change and the global efforts to mitigate it.

(5) There are potential long-term benefits in solving local collective action problems surrounding food security improvements via adaptation for solving global issues. If local communities do not internalize the global mitigation costs, local adaptation projects can provide a better way to subsidize building future awareness to climate change and its impacts and create more effective local collective action frameworks.[29]

III. EFFECTIVE ADAPTATION EXAMPLES

What are some actual local adaptation solutions that can both improve food security and help in promoting global mitigation? One example is initiatives that emphasize planting resilient crops, crops that require less water, and/or crops that were engineered to produce higher yields. This approach has been at the heart of the Green Revolution to transition agriculture across the developing world between the mid-1960s and the mid-2000s.[30] By relying on more efficient crops, the Green Revolution—the widespread distribution of effective agricultural technology and resilience crops to many areas of the developing world—has lifted millions worldwide from food insecurity and hunger by both improving production (improving availability) and reducing local prices (improving access).[31] Over the same period, the Green Revolution has also saved an estimated 17.9–

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[29] *See* Dietz, Ostrom & Stern *supra* note 16, at 1907–09; Ostrom, *supra* note 8, at 15–16.

[30] *See* Prabhu L. Pingali, *Green Revolution: Impacts, Limits, and the Path Ahead*, 109 PROC. NAT'L ACAD. SCI. 12302, 12302 (2012).

[31] *See id.* at 12303.

26.7 million hectares from becoming agricultural land.[32] Reducing the insensitivity of agricultural production also means less energy is used to tend the fields, which lowers emissions. In countries where the Green Revolution was ineffective, including in many African states,[33] adapting to climate change by improving food security can help in mitigating emissions in these regions over the coming decades.

Another solution is to rely on irrigation techniques that reduce heat generation and the amount of water used. For example, microirrigation technologies deliver the water slowly and over a longer period, which helps in preventing runoff evaporation and uses 20–50 percent less water than conventional sprinkler systems.[34] Electrostatic spray technology (EST) is an approach that can be implemented across a variety of fields, including not only agricultural production but also material and petroleum engineering, and optimizes the use of liquid according to specific parameters.[35] EST can lower water use intensively, reduce heat generation, and prevent pesticide spillovers, while mitigating emissions and improving agricultural output.[36]

A third example of an adaptation approach with effective mitigation externalities is to leapfrog current refrigeration technologies to low global warming potential (GWP) ones.[37] It is even possible to use natural cooling (e.g., by constructing granaries and food storage facilities) using materials that offer insulation capacities. Granted, relying on this solution might not provide as effective of an adaptation as some more easily available or energy intensive solutions. But, they will still help to improve local food security while also reducing future emissions, thereby maximizing their mitigation externalities.

IV. CONCLUSION

The findings from our modeling exercise provide some useful insights for how to address the complicated collective action problem that hampers achieving successful mitigation. In essence, the results suggest that the mitigation externalities resulting from investments in

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[32] James R. Stevenson, Nelson Villoria, David Byerlee, Timothy Kelley & Mywish Maredia, *Green Revolution Research Saved an Estimated 18 to 27 Million Hectares from Being Brought into Agricultural Production*, 110 PROC. NAT'L ACAD. SCI 8363, 8363 (2013).

[33] *See* Pingali, *supra* note 30, at 12305.

[34] R.K. Sivanappan, *Prospects of Micro-Irrigation in India*, 8 IRRIGATION & DRAINAGE SYS. 49, 52 (1994).

[35] *See* Junfeng Wang, Yating Zhang, Wei Zhang & Zhiheng Fan, *Research Progress of Electrostatic Spray Technology Over the Last Two Decades*, 147 J. ENERGY ENG'G 1, 1 (2021).

[36] *See generally id.*

[37] *See* Yabin Dong, Marney Colema & Shelie A. Miller, *Greenhouse Gas Emissions from Air Conditioning and Refrigeration Service Expansion in Developing Countries*, 46 ANN. REV. ENV'T & RES. 59, 70 (2021).

locally adapting to climate change's impacts work, in effect, like a "tax." In pushing for adaptation projects that may achieve suboptimal food security outcomes locally but that also generate greater mitigation externalities (e.g., by adopting potentially less effective low GWP cooling over high-capacity technologies), locals forgo some of the benefits of optimized adaptation rather than being directly taxed for improving mitigation (e.g., by paying higher gas prices). Prospect Theory suggests that this might be an easier way of getting individuals to contribute to mitigation efforts, seeing that individuals are more open to limiting their gains rather than losing resources they already possess.[38]

The results also illustrate how local solutions can translate into global impacts. Climate change's potential effects—not only by harming food security in some regions—unfold over different levels of resolution. Employing a "glocal" approach to thinking of flexible solutions can yield new approaches to dealing with climate change and its effects.

V. SUPPLEMENTAL APPENDIX FOR FROM LOCAL ADAPTATION TO GLOBAL MITIGATION: HOW IMPROVING FOOD SECURITY BY BUILDING LOCAL RESILIENCE CAN HELP LIMIT CLIMATE CHANGE

Collective action model à la Mancur Olson

The following proposition characterizes the equilibrium for the Olsonsian collective action model with payoffs given by equation (1):

Proposition 1: *If* $N < \frac{B}{c}$ *, then the unique Nash equilibrium is* C_i *for all I. If* $N > \frac{B}{c}$ *, then the unique Nash equilibrium is* D_i *for all i.*

Proof: see Anauati et al.[39]

The donor's problem

As discussed in Part II, consider a donor that only cares about global mitigation and counts with a budget R.

Case 1: A simple case of adaptation to climate-induced food insecurity.

Assume that $c_G N_G - B_G > c_l N_l - B_l = c_L N_L - B_L$ and $\beta_l = \beta_L$ for all issues l (local adaptation issues are identical). There are only two possible situations to consider depending on whether collective action for global mitigation is funded or not. Suppose that collective action for global mitigation is funded. Then, Proposition 1 implies that $c_G N_G - B_G$

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[38] *See* Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk,* 47 ECONOMETRICA 263, 274–75 (2013).

[39] *See* Anauati, Feld, Galiani, & Torren, *supra* note 27, at 40–41.

dollars will be required for such purpose (i.e., a subsidy of $c_G - \frac{B_G}{N_G}$ per individual) and, hence, the amount available for subsidizing local collective action issues will be $R - c_G N_G + B_G$. Then, Proposition 1 implies that $\frac{R-c_G N_G+B_G}{c_L N_L - B_L}$ local issues can be advanced (given that each local issue requires a subsidy of $c_L - \frac{B_L}{N_L}$ per individual), resulting in total mitigation benefits of $B_G + \frac{R-c_G N_G+B_G}{c_L N_L - B_L}\beta_L B_L$. On the contrary, suppose that collective action for the global issue is not subsidized. Then, Proposition 1 implies that $\frac{R}{c_L N_L - B_L}$ local collective action issues will be advanced, resulting in total mitigation benefits of $\frac{R}{c_L N_L - B_L}\beta_L B_L$. Comparing mitigation benefits for these two funding choices shows that the donor will subsidize local collective action issues if and only if $\beta_L > \frac{(c_L N_L - B_L)}{(c_G N_G - B_G)}\frac{B_G}{B_L}$.

Case 2: A case of adaptation projects with varying mitigation externality impacts.

Following the same logic employed in Case 1, we deduce that total mitigation benefits when all the budget is allocated to local adaptation projects with high-externality effects on global mitigation are greater than when part of the budget is allocated to global mitigation if and only if $\beta_L^H > \frac{(c_L N_L - B_L)}{(c_G N_G - B_G)}\frac{B_G}{B_L}$.

Collective action model à la Thomas C. Schelling- Elinor Ostrom

The following proposition characterizes the equilibrium for the Schelling-Ostrom model of collective action with payoffs given by equation (4):

Proposition 2: If $N < \frac{B+s}{c}$, then C_i for all i is the unique Nash equilibrium. If $N > \frac{B+s}{c}$, there are three Nash equilibria: C_i for all i, D_i for all i, and $\alpha_i = \hat{\alpha} = \frac{cN-B-s}{s(N-1)}$ for all i. Moreover, in the third Nash equilibrium, the expected share of cooperators is $\mathbf{E}\left[\frac{k}{N}\right] = \hat{\alpha}$.

Proof: see Anauati et al.[40]

Suppose that we use the mixed strategy equilibrium to compute the probability of occurrence of the two pure strategy equilibria. Assuming that the share of expected cooperators is distributed according to the uniform distribution (Laplacian assumption), we have:[41]

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[40] *See id.* at 41–42.

[41] *See id.*; MEDINA, *supra* note 27, at 94–96.

$$\Pr\ (C_i \text{ for all } i\ ) = \frac{(s-c)N+B}{s(N-1)}$$

The donor's problem

As discussed in Part II, consider a donor that only cares about global mitigation and counts with a budget R. Assume that $c_G N_G - B_G > c_l N_l - s_l - B_l = c_L N_L - s_L - B_L$ and $\beta_l = \beta_L$ for all issues l (local adaptation issues are identical). Suppose that collective action for global mitigation is funded. Then, Proposition 1 implies that $c_G N_G - B_G$ dollars will be required for such purpose (i.e., a subsidy of $\tau_G = c_G - \frac{B_G}{N_G}$ per individual), and, hence, the amount available for subsidizing local collective action issues will be $R - c_G N_G + B_G$. Then, Proposition 2 (combined with the techniques employed to deduce the probability of collective action and the Laplacian assumption on beliefs) implies that $\frac{R-c_G N_G+B_G}{c_L N_L - s_L - B_L}$ local adaptation issues can be fully advanced (given that each local issue requires a subsidy of $\tau_l = \frac{c_l N_l - s_l - B_l}{N_l}$ per individual), resulting in total expected mitigation benefits of

$$B_G + \frac{R - c_G N_G + B_G}{c_L N_L - s_L - B_L}\beta_L B_L + \frac{(s_L - c_L)N_L + B_L}{s_L(N_L-1)}\left[P - \frac{R - c_G N_G + B_G}{c_L N_L - s_L - B_L}\right]\beta_L B_L$$

where P is the number of all local issues. On the contrary, suppose that collective action for the global issue is not subsidized. Then, Proposition 2 (combined with the techniques employed to deduce the probability of collective action and the Laplacian assumption on beliefs) implies that $\frac{R}{c_L N_L - s_L - B_L}$ local issues can be fully advanced, resulting in total expected mitigation benefits of

$$\frac{R}{c_L N_L - s_L - B_L}\beta_L B_L + \frac{(s_L - c_L)N_L + B_L}{s_L(N_L-1)}\left[P - \frac{R}{c_L N_L - s_L - B_L}\right]\beta_L B_L$$

Comparing these expected payoffs, we have that the donor should only fund local adaptation issues if and only if

$$\beta_L > \frac{s_L(N_L-1)B_G}{(c_G N_G - B_G)B_L}$$