Food Security, Nutrition, and Climate Resilience Evidence Review

Working paper

OCTOBER 2024

Innovation Commission:
Climate Change
Food Security
Agriculture

IFAD
Investing in rural people

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Acknowledgements

The Food Security, Nutrition, and Climate Resilience Evidence Review is a product of the Secretariat of the Innovation Commission for Climate Change, Food Security, and Agriculture. Technical advice and feedback were received from a review panel including: Tilman Brück (IGZ, HU Berlin and ISDC), Maximo Torero Cullen (FAO), Andrew Dillon (Northwestern Kellogg), Andrew Kaiser-Tedesco (GIZ), Florence Kondylis (DIME, World Bank), Karen Macours (PSE, INRAE), Jyotsna Puri (IFAD and Columbia University), and Paul Winters (Notre Dame). Drafting and editing of the report included contributions from:: Michelle Cherian (Senior Research Associate, Development Innovation Lab), Joshua Deutschmann (Research Lead, Development Innovation Lab), Christlee Elmera (Research Professional, Development Innovation Lab), Kyle Murphy (Director, Development Innovation Lab), Mauricio Ortiz-Riomalo (Senior Research Professional, Development Innovation Lab), Jess Rudder (Post-doctoral scholar, Development Innovation Lab), Imara Salas (Senior Manager, Development Innovation Lab). Additional research support was provided by: Colley Buwana, Grant Castle, Julia Higgins, Riddhi Kankaria, Anthony Khaiat, Yuhang Li, Henrique Mota, Konstantin Shmarko, and Cole Weaver.

This report was made possible thanks to the funding from the Transitional Development Assistance Programme of the German Federal Ministry for Economic Cooperation and Development (BMZ), and the International Fund for Agricultural Development (IFAD). The project was undertaken in cooperation with the German Corporation for International Cooperation GmBH (GIZ) and IFAD. The views and opinions expressed in this paper are solely those of the authors and should not be attributed to the donors, to IFAD, its Member States, or their representatives to its Executive Board. All content is the responsibility of the authors, and any remaining errors are our own.

Niek de Greef (NDG Design) provided the design for the publication

Suggested Citation: Murphy, K., Rudder, J., Cappucci, M., Cherian M., Deutschmann, J., Elmera, C., Fundukova, L., Kaiser-Tedesco, A., Ortiz-Riomalo, A., Puri, J., Salas, I., Songsermsawas, T. (2024). *Evidence Review for Food Security, Nutrition, and Climate-Resilience Interventions*.

Executive summary

This report presents an analysis of the impact and cost-effectiveness of 40 common interventions in food security, nutrition, and climate resilience. These include interventions related to production systems, post-harvest management and processing, food availability and affordability, financial services, governance, nutritional health, and behavior change communication. The report aims to provide a resource for policymakers in the food and nutrition space to understand the evidence behind various interventions.

This analysis is based on a review of 600 peer-reviewed, published studies and academic working papers with well-identified causal designs. Studies were included that 1) relied on a well-identified causal design, 2) were conducted in low- or middle-income settings, 3) were published or released as academic working papers after the year 2000, and 4) measured outcomes of interest related to food and nutrition security or climate resilience. The analysis includes studies with experimental designs–such as randomized control trials–or high-quality quasi-experimental designs, as well as meta-analyses. Some non-experimental academic studies are cited in the report when they provide important context and background information. To be included, studies had to measure primary outcomes associated with food security (yield, profit, income, consumption, etc.), nutrition (BMI, prevalence of anemia, etc.), and climate (reforestation, resilience to shock, etc.).

Overall Category Methodology

Each intervention is given an "overall category" , which combines a summary of the evidence base (see Evidence Assessment Methodology section for details), and considerations related to cost-effectiveness, geographic variation, adoption, and scalability. We also convened an expert panel to assess the evidence and determine categorization.

We consider an intervention to have an impact if it has positive and significant treatment effects for target outcomes related to food, nutrition, and climate resilience. In some cases, interventions may measure non-target outcomes, but these are not included in this review. For example, school feeding programs may have a significant positive impact on school attendance, but school attendance is not one of the main outcomes under consideration. Similarly, many agricultural interventions may increase input expenditure but lack evidence on outcomes that directly improve food security, such as productivity, profits, or income.

The assessment of cost-effectiveness relied on estimates provided in publications. Where estimates of cost-effectiveness were unavailable, we provide a summary of whether an intervention has a plausible pathway to cost-effectiveness based on features of implementation. In those assessments, we first considered how much interventions would need to be tailored to local contexts which contributes to higher fixed costs to initiate projects. Second, we considered the variable or marginal cost of delivery. For example, digital extension interventions may have high start-up costs but have very low delivery costs when using mobile phones, TV, or radio.
Relatedly, interventions that have been tested in numerous geographies and with consistent evidence of adoption were more likely to reach the 'Good Evidence' category.

It is important to note that being categorized as Low or Mixed Evidence does not necessarily mean that interventions are not worth investing in. In many cases, these interventions would benefit from more research to identify scalable models that work well in numerous settings. It can be difficult to implement research on a large-scale enough scale to identify all the potential mechanisms and avenues for impact. As a result, some public sector interventions are underrepresented in the evidence base because they are

large-scale public works (irrigation) or because they are difficult to randomize (traditional agricultural extension, agricultural supply chains, public works programs in Africa, land tenure governance).

We also predominantly focused on economics journals and outlets and focused on studies that study target populations. This means that we mostly exclude agronomic studies in controlled settings, clinical trials, or laboratory studies. For nutrition studies, we relied more heavily on systematic reviews and meta-analyses, which are more common in public health fields, compared to economics.

Overall Category Findings:

The overall categories for each intervention combine the assessment of the volume of the evidence base, impact, and cost-effectiveness. Our assessment resulted in the following rankings.

Great Evidence exhibited both a considerable volume of evidence and consistent findings across the evidence in all outcome categories where evidence is available. There was also high-quality evidence of cost-effectiveness and evidence that programs were effective in a range of contexts.

- Cash and in-kind transfers
- Graduation programs

Good Evidence also had a considerable volume of evidence and consistent findings in at least one main outcome category (food security, nutrition, and/or climate resilience). Compared to the great category, these interventions were more likely to require tailoring interventions to new contexts, which raises implementation costs, or there were examples of low adoption in some contexts. In most cases, there is evidence of cost-effectiveness.

- R&D for improved crop varieties
- Delivery of improved crop varieties
- Training and information diffusion
- Improved food storage
- Digital extension services
- Improved Infant and Young Child Feeding Practices
- Fortification
- Nutrition campaigns

High Potential Evidence had consistent results, but a lower volume of evidence or significant open questions. These interventions have yet to be extensively studied in the literature, but they show high potential for implementation at scale. They tend to have less evidence of cost-effectiveness but have plausible pathways to cost-effectiveness at scale.

- Biofortified crops
- Weather forecasting
- Bundled interventions
- Climate-smart agriculture
- Veterinary services
- Livestock management practices
- Land governance and tenure regularization
- Adaptive social protection
- Aggregation and output markets

- Alternative protocols for the management of acute malnutrition, including therapeutic feeding
- Community health workers

Mixed Evidence interventions have a large volume of evidence with mixed findings in terms of adoption, impact on primary outcomes related to food, nutrition, and climate resilience, or high variation across contexts. In some cases, this is because an intervention works in some settings and not others or that a category of interventions lacked consistent impact in terms of evidence-based efficacy, cost-effectiveness, adoption, or scalability. In other cases, there is high-quality evidence that specific programs were effective in one or two contexts, but these were balanced by unsuccessful programs in other contexts (agricultural credit, insurance, payments for ecosystem services, fertilizer input subsidies). These programs should be tested at scale or in new contexts.

- Public work programs
- Agricultural credit
- Insurance designed for farmers
- Seasonal migration
- Agricultural supply chains
- Payments for ecosystem services
- Savings groups
- Technical and vocational training
- Fertilizer and other inputs access
- School feeding programs

Low Evidence interventions had a low volume of evidence where it was not possible to draw a definitive conclusion about the impact or cost-effectiveness of interventions. In some cases, interventions had numerous descriptive studies but lacked evidence from high-quality, causal research designs (e.g. traditional agricultural extension, integrated pest management). In other cases, there was not enough evidence of positive effects in rural communities, even though there were one or two papers with high-quality evidence from urban areas (e.g. business skills for small businesses, on-farm mechanization, and supplementation).

- Traditional agricultural extension
- Integrated pest management
- Improved irrigation
- On-farm mechanization
- Business skills for small businesses
- Supplementation
- Home gardens
- Professional Services (dieticians/nurses)
- Cooking Classes

Evidence Assessment Methodology

The Evidence Assessment focuses specifically on the strength of the evidence base behind each intervention, considering the volume of studies and the consistency of findings across evaluations. It does not consider cost-effectiveness, scalability, adoption, or geographic variation. It is an input to determining the overall category balanced by considerations that are not perfectly captured by headline outcomes reported in publications (such as adoption or scalability).

For the evidence assessment, we counted the total number of papers per intervention area that met the inclusion criteria. When at least half of the publications found a positive and significant impact in each main outcome area, the intervention was considered to have 'highly consistent' evidence. Mechanically, this may be a relatively low bar for interventions with few papers (for example, if there are two publications that study one intervention, only one needs to find positive effects). Therefore, we both noted the total number of publications and per outcome area. Interventions with more than seven publications were considered to have a 'high volume' of evidence. The cutoff of seven was chosen because it is the median number of papers per category.

When intervention areas had a high volume and consistency of findings, they were eligible for the Good and Great Evidence grouping in the overall category (with one exception for Improved Infant and Young Child Feeding Practices, which had significant overlap with nutrition campaigns). If interventions had both high consistency and high volume of evidence, they could be categorized as mixed, high potential, good, or great, depending on the nuances of the evidence base as described in the Overall Category Methodology section. If studies had a low volume of evidence, they were eligible to be categorized as low, mixed, or high potential.

The companion spreadsheet provides details on the volume and consistency of evidence for each intervention, broken out by food security, nutrition, and climate resilience outcomes. We do not report results on individual outcomes categories in the main body of the report.

Figure 1: Strength of evidence

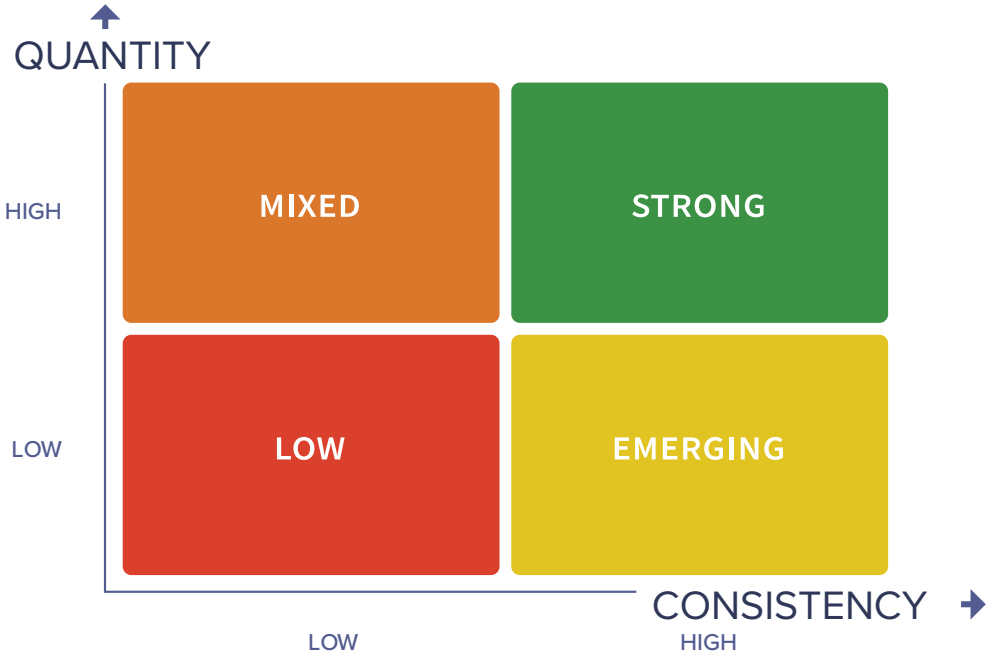

Figure 2: Intervention ranking

BIBLIOGRAPHY

Bates, Mary Ann, and Rachel Glennerster. "The Generalizability Puzzle." *Stanford Social Innovation Review* 15 (2017): 5054. https://doi.org/10.48558/EYY5-3S89.

Contents

Financial services interventions

Governance interventions

Nutritional health

Behavior change communication

Appendix

Production systems interventions

This section categorizes 15 production systems interventions based on the strength of the underlying evidence, impact on relevant outcomes, and value for money.

1. R&D for improved crop varieties

Research & Development (R&D) for improved crop varieties covers the identification and development of seeds with a wide variety of traits and characteristics, including breeding for higher yields, climate resilience, chemical and pest resistance, as well as adapting existing seeds to niche agro-ecological zones or shifting environmental contexts. Farmers who adopt high-yielding and/or climate-resilient varieties strengthen agricultural resilience by increasing crop yields and income, particularly in years with adverse weather conditions. The adoption of this improved technology has also been key to agricultural and structural transformation. In Brazil, for instance, the authorization of planting and commercialization of genetically engineered soybean seeds increased agricultural production per worker and reduced labor intensity in agriculture (Bustos et al., 2016). Overall, there is **good evidence** from real-world studies with farmers of the impact of R&D for improved seeds on productivity, incomes, climate resilience, and food and nutrition security. However, its cost-effectiveness can vary depending on existing seed markets and the development process of new varieties.

Green Revolution high-yielding varieties, developed and adopted in the latter half of the 20th century, provide good evidence of the impact of improved seeds on health and nutrition. A study of 84 countries finds that between 1960 and 2000, a 10 percentage point increase in HYV adoption increased GDP per capita by about 15 percent and increased life expectancy by 1.34 percent (Gollin et al., 2021). Another study using data from 37 countries finds that, between 1961 and 2000, an increase in modern seed variety (MVs) adoption from 0 to 50 percent led to a decline in infant mortality from 71 to 38 deaths per 1,000 children and significantly reduced severe stunting, though not severe wasting, underweight, or low birthweight (von der Goltz et al., 2020). Finally, a study in India from 1966 to 1998 finds that an increase of one standard deviation in HYV adoption led to a 0.50 percentage point decrease in infant mortality (Bharadwaj et al., 2020). However, the improvement in female infant mortality was only half that of male infant mortality.

Ongoing crop improvements provide additional evidence of positive impacts. For example, locally adapted seeds bred for targeted agro-ecological zones can drastically improve farmer outcomes. In Kenya, where most seed development had previously focused on high-altitude areas, the introduction of new mid-altitude varieties led to significant increases in yields for adopters (Bird et al., 2022). In Guinea, distributing samples of an iron-tolerant rice seed suitable for lowland cultivation increased farmer yields by 26 percent and profit per hectare by 45 percent (Arouna, 2022).

Crop varieties developed to withstand climate stressors, like flood-, heat-, and salinity-tolerant seeds have also proven effective in increasing resilience and protection from climate shocks and to increase productivity during normal years. The introduction of a flood-tolerant rice variety in India led to reduced yield variability and significant improvements in yields that increase as flood severity worsens (Dar et al., 2013). It also reduced risk, thereby incentivizing farmers to adopt other improved agricultural practices with

the potential to increase yields even in non-flood years (Emerick et al., 2016). In Mozambique and Tanzania, access to a combination of index insurance and stress-tolerant seeds improved farmers' resilience to midseason droughts, mitigated yield loss throughout the study period by enabling yields to 'bounce back' from shocks, and erased the negative impacts of drought shocks on food security (Boucher et al., 2021).

Finally, there is some evidence that pest-resistant seeds can improve productivity and reduce costs. For example, Bt cotton was developed to resist bollworm, a major pest in cotton production. In Pakistan, the adoption of Bt cotton improved net farmer yields by 25 percent - largely by avoiding damages rather than increasing yields - and reduced pesticide application (Kouser and Qaim, 2014). Other studies on Bt cotton have described some limitations and unintended consequences related to increased production costs in India and Pakistan (Qaim et al 2006; Bakhsh, 2017). In Pakistan, Bt seed use increases irrigation, a factor to consider in places with a high water demand (Bakhsh, 2017).

Adoption: Constraints to the adoption of improved seeds are covered in the review, " Delivery of improved crop varieties." In terms of R&D, a primary challenge for developing appropriate improved seeds is the persistent gap between yields under controlled agronomic trials and real-world conditions. A variety of factors help explain this gap, including the type of farmers selected for agronomic trials, parcel selection, and the degree of researcher involvement in controlling conditions (Laajaj et al., 2020). One takeaway from this work is that any investment in developing new varieties should consider incorporating iterative testing in real-world settings. The studies referenced in this review are all based on real-world applications rather than agronomic trials.

Cost-effectiveness: Unclear, likely highly cost-effective when adoption is high. May have high fixed costs to develop and promote new varieties and lower marginal costs to deliver new varieties. In general, if new seeds require similar or fewer inputs from farmers, cost a similar amount for farmers to purchase, and improve yields or reduce losses, we should expect these to be profitable investments. Due to measurement costs, it can often be challenging to detect income improvements in practice. Nevertheless, some evidence on rice in Guinea points in this direction (Arouna, 2020).

Context: Local context plays an important role in the effectiveness of improved varieties, as covered in review #2, *Delivery of improved crop varieties*.

BIBLIOGRAPHY

Arouna, Aminou. "Enhancing Rice Farmers' Food Security Through Adaptation to Iron Toxicity in Lowlands: Evidence from a Randomized Control Trial in Guinea." SSRN Scholarly Paper. Rochester, NY, April 4, 2020. https://doi.org/10.2139/ssrn.3592455.

Bakhsh, Khuda. "Impacts of Bt Cotton on Profitability, Productivity and Farm Inputs in Pakistan: Use of Panel Models." *Environment and Development Economics* 22, no. 4 (2017): 373–91. https://www.jstor.org/stable/26392699.

Bharadwaj, Prashant, James Fenske, Namrata Kala, and Rinchan Ali Mirza. "The Green Revolution and Infant Mortality in India." *Journal of Health Economics* 71 (May 2020): 102314. https://doi.org/10.1016/j.jhealeco.2020.102314.

Bird, Samuel S., Michael R. Carter, Travis J. Lybbert, Mary Mathenge, Timothy Njagi, and Emilia Tjernström. "Filling a Niche? The Maize Productivity Impacts of Adaptive Breeding by a Local Seed Company in Kenya." *Journal of Development Economics* 157 (June 1, 2022): 102885. https://doi.org/10.1016/j.jdeveco.2022.102885.

Boucher, Stephen, Michael Carter, Jon Einar Flatnes, Travis J. Lybbert, Jonathan Malacarne, and Laura Paul. "Bundling Stress Tolerant Seeds and Insurance for More Resilient and Productive Small-Scale Agriculture." *SSRN Electronic Journal*, 2021. https://doi.org/10.2139/ssrn.3922508.

Bustos, Paula, Bruno Caprettini, and Jacopo Ponticelli. "Agricultural Productivity and Structural Transformation: Evidence from Brazil." *American Economic Review* 106, no. 6 (June 2016): 1320–65. https://doi.org/10.1257/aer.20131061.

Dar, Manzoor H., Alain de Janvry, Kyle Emerick, David Raitzer, and Elisabeth Sadoulet. "Flood-Tolerant Rice Reduces Yield Variability and Raises Expected Yield, Differentially Benefitting Socially Disadvantaged Groups." *Scientific Reports* 3, no. 1 (November 22, 2013): 3315. https://doi.org/10.1038/srep03315.

Emerick, Kyle, Alain de Janvry, Elisabeth Sadoulet, and Manzoor H. Dar. "Technological Innovations, Downside Risk, and the Modernization of Agriculture." *American Economic Review* 106, no. 6 (June 2016): 1537–61. https://doi.org/10.1257/aer.20150474.

Gollin, Douglas, Casper Worm Hansen, and Asger Wingender. "Two Blades of Grass: The Impact of the Green Revolution," n.d.

Goltz, Jan von der, Aaditya Dar, Ram Fishman, Nathaniel D. Mueller, Prabhat Barnwal, and Gordon C. McCord. "Health Impacts of the Green Revolution: Evidence from 600,000 Births across the Developing World." *Journal of Health Economics* 74 (December 2020): 102373. https://doi.org/10.1016/j.jhealeco.2020.102373.

Kouser, Shahzad, and Matin Qaim. "Bt Cotton, Damage Control and Optimal Levels of Pesticide Use in Pakistan." *Environment and Development Economics* 19 (December 1, 2013): 704–23. https://doi.org/10.1017/S1355770X1300051X.

Laajaj, Rachid, Karen Macours, Cargele Masso, Moses Thuita, and Bernard Vanlauwe. "Reconciling Yield Gains in Agronomic Trials with Returns under African Smallholder Conditions." *Scientific Reports* 10, no. 1 (August 31, 2020): 14286. https://doi.org/10.1038/s41598-020-71155-y.

Qaim, Matin, Arjunan Subramanian, Gopal Naik, and David Zilberman. "Adoption of Bt Cotton and Impact Variability: Insights from India." *Review of Agricultural Economics* 28, no. 1 (2006): 48–58. https://www.jstor.org/stable/3700846.

2. Delivery of improved crop varieties

Interventions to distribute improved seeds aim to address a variety of barriers to improved seed adoption faced by farmers, including farmer-level constraints (e.g. credit, risk, and information constraints) and market-level issues (e.g. quality control, fragmented distribution channels, and information about prices, availability, and complementary practices) to induce adoption and related outcomes. Examples of programs include providing subsidies, free distribution, microcredit, in-kind transfers, or information resources. Expanding access to improved seeds can also lead farmers to adopt complementary inputs that mitigate yield losses caused by adverse climate conditions. These interventions are broadly backed by **good evidence** on agricultural productivity, income, and climate resilience. However, there is limited evidence of their effects on nutrition and food security.

Adoption: Farmers often forgo adopting potentially profitable inputs, such as improved seeds, due to heterogeneous returns, present bias, asymmetric information, lack of access to complementary inputs like irrigation or fertilizers, and liquidity constraints. Farmers who would benefit most from adopting improved seeds may face the highest fixed costs due to poor access to seed and fertilizer distributors or poorly interlinked or shallow markets to sell surplus production (Suri, 2011). Alternatively, present-biased farmers may choose to defer the cost of purchasing seeds until the last moment possible and ultimately fail to invest, based on evidence from Kenya and Bangladesh (Duflo et al., 2011; Chowdhury et al., 2020). Concerns about the proliferation of counterfeit or deficient seeds may also disincentivize farmers from purchasing new, improved seeds (Bold et al., 2017; Hsu and Wambugu, 2023).

Addressing supply and demand constraints together can induce higher adoption of improved seeds, though the effects on productivity are mixed. Evidence from Uganda suggests that stimulating supply by creating informal supply chains and demand by demonstrating the benefits of improved seeds and distributing free samples can significantly boost adoption that persists after the program phase-out (Fishman et al., 2017). Stimuli of supply and demand were accompanied by a week-long training in improved sustainable cultivation practices that also led to sustained adoption of practices like crop rotation, intercropping, line sowing, weeding, irrigation, and pest and disease management (Fishman et al., 2017). In Bangladesh, providing biofortified seeds for home gardens and a one-day training program led to sustained impacts on yields three years after the intervention, though the effects on vegetable intake declined over time (Baliki et al., 2019; Baliki et al., 2022). Also in Bangladesh, however, a program that combined info sessions for farmers with support to retailers found no evidence of higher yields, as most farmers did not follow recommended seeding rates (de Brauw et al., 2020). This intervention suggests that targeted extension may be a key complementary component (de Brauw et al., 2020).

Providing access to complementary technologies can also enhance improved seed adoption levels. In Uganda, commonly promoted high-yielding maize offers less natural protection against insect attacks during storage than traditional varieties. In response, a program that gave farmers Purdue Improved Crop Storage (PICS) hermetic bags was effective at inducing adoption. Farmers also stored maize for longer periods, reported a substantial drop in storage losses, and were less likely to use storage chemicals

(Omotilewa et al., 2018). Despite their benefits, the adoption of similar PICS bags is constrained. Evidence from Niger suggests that while PICS are profitable for small-scale farmers, adoption is constrained by variation in supply, not informational or liquidity constraints (Aker et al., 2023). Further evidence from an experimental auction in Kenya suggests that text messaging can disseminate information on the improved bags and that a one-time price subsidy could spur demand and adoption (Channa et al., 2019).

Designing interventions to address behavioral biases may help bridge some of these barriers and increase adoption. In Bangladesh, a microcredit intervention that offered a standard microcredit contract with a commitment mechanism enhanced technology adoption among present-biased farmers, whose output and profits also increased (Chowdhury et al., 2020). In Uganda, timing the sale of hybrid seeds to coincide with harvest - when farmers are most liquid - also increased adoption (Axmann et al., 2020). In Bangladesh, demonstration plots of any size were broadly effective at increasing the adoption of flood-tolerant seeds, but adoption decreased after two years as farmers learned more about how seeds worked on their plots (Kondylis et al., 2023). Adoption of these improved seeds reduced the adverse impact of saline floods almost to zero, which represented an increase in yields and profits per hectare (Kondylis et al., 2023).

Context: Overall, there isn't much evidence pointing to how contextual differences can affect the effectiveness of these interventions. Using private input dealers as information agents can be significantly more effective at inducing improved seed adoption than government channels (Dar et al., 2020). One aspect that has been documented is contextual heterogeneity, which plays an important role when leveraging social networks to diffuse technologies. Evidence from Uganda and Malawi suggests that technologies can be effectively diffused by individuals at the core of local social networks (Fishman et al., 2017; Beaman et al., 2021). However, variations in soil fertility within a village can dampen social learning effects (Tjernström, 2017). Targeting women may also enhance the productivity effects of relevant interventions. While female farmers may be less likely to take up improved varieties initially, evidence from Uganda shows that those who purchase improved seeds were four times more likely to plant them than male farmers (Axmann et al., 2020). In fragile and conflict-affected contexts, even providing standard (non-improved) seeds and crop varieties may result in significant positive improvements in food security (Weiffen et al., 2022).

Cost-effectiveness: Unclear but likely highly cost-effective when adoption is high. May have high fixed costs to develop and promote new varieties and lower marginal cost to deliver new varieties. There is limited experimental evidence of the cost-effectiveness of delivering improved crop varieties in isolation. Regardless, the cost-effectiveness of these interventions may depend on whether the improved varieties are hybrids, which only give high returns for one season, or vegetatively propagated crops, which farmers can multiply themselves to maintain high returns for multiple seasons. Vegetative propagated crops, which need to be renewed for maximum effectiveness but can be saved for several seasons, may prove more cost-effective, but this depends crucially on relative prices and yields compared to hybrid varieties.

Aker, Jenny C, Brian Dillon, and C. Jamilah Welch. "Demand, Supply and Long-Term Adoption: Evidence from a Storage Technology in West Africa." Google Docs, 2022. https://drive.google.com/file/d/1Aziw-jkJ-ReZP1F1UOW4LuNNsUFsrLVkD/view?usp=embed_facebook.

Axmann, Nikolaus, Torben Fischer, Kevin Keller, Kevin Leiby, Daniel Stein, and Paul Wang. "Access and Adoption of Hybrid Seeds: Evidence from Uganda." *Journal of African Economies* 29, no. 3 (May 1, 2020): 215–35. https://doi.org/10.1093/jae/ejz019.

Baliki, Ghassan, Tilman Brück, Pepijn Schreinemachers, and Md. Nasir Uddin. "Long-Term Behavioural Impact of an Integrated Home Garden Intervention: Evidence from Bangladesh." *Food Security* 11, no. 6 (December 1, 2019): 1217–30. https://doi.org/10.1007/s12571-019-00969-0.

Baliki, Ghassan, Pepijn Schreinemachers, Tilman Brück, and Nasir Md. Uddin. "Impacts of a Home Garden Intervention in Bangladesh after One, Three and Six Years." *Agriculture & Food Security* 11, no. 1 (September 10, 2022): 48. https://doi.org/10.1186/s40066-022-00388-z.

Beaman, Lori, Ariel BenYishay, Jeremy Magruder, and Ahmed Mushfiq Mobarak. "Can Network Theory-Based Targeting Increase Technology Adoption?," n.d.

Brauw, Alan de, Berber Kramer, and Mike Murphy. "Yielding Profits? Low Adoption of an Improved Mung Bean Seed Variety in Southern Bangladesh." SSRN Scholarly Paper. Rochester, NY, November 19, 2020. https://papers.ssrn.com/abstract=3736255.

Channa, Hira, Amy Z. Chen, Patricia Pina, Jacob Ricker-Gilbert, and Daniel Stein. "What Drives Smallholder Farmers' Willingness to Pay for a New Farm Technology? Evidence from an Experimental Auction in Kenya." *Food Policy* 85 (May 2019): 64–71. https://doi.org/10.1016/j.foodpol.2019.03.005.

Chowdhury, Shyamal, Joeri Smits, and Qigang Sun. "Contract Structure, Time Preference, and Technology Adoption." *SSRN Electronic Journal*, 2020. https://doi.org/10.2139/ssrn.3674311.

Dar, Manzoor H., Alain De Janvry, Kyle Emerick, Elisabeth Sadoulet, and Eleanor Wiseman. "Private Input Suppliers as Information Agents for Technology Adoption in Agriculture." *American Economic Journal: Applied Economics* 16, no. 2 (April 1, 2024): 219–48. https://doi.org/10.1257/app.20220037.

Duflo, Esther, Michael Kremer, and Jonathan Robinson. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." *American Economic Review* 101, no. 6 (October 2011): 2350–90. https://doi.org/10.1257/aer.101.6.2350.

Fishman, Ram, Stephen C. Smith, Vida Bobić, and Munshi Sulaiman. "Can Agricultural Extension and Input Support Be Discontinued? Evidence from a Randomized Phaseout in Uganda." *The Review of Economics and Statistics* 104, no. 6 (November 14, 2022): 1273–88. https://doi.org/10.1162/rest_a_01029.

Fishman, Ram, Stephen C Smith, Vida Bobić, and Munshi Sulaiman. "How Sustainable Are Benefits from Extension for Smallholder Farmers? Evidence from a Randomized Phase-Out of the BRAC Program in Uganda," 2017. https://www.iza.org/publications/dp/10641/how-sustainable-are-benefits-from-extension-for-smallholder-farmers-evidence-from-a-randomized-phase-out-of-the-brac-program-in-uganda.

Hsu, Eric, and Anne Wambugu. "Can Informed Buyers Improve Goods Quality? Experimental Evidence from Crop Seeds*." Google Docs, 2024. https://drive.google.com/file/d/15Ad_PdGI0-gQxJr9snYKKQMyx5HCjJZt/view?usp=embed_facebook.

Kondylis, Florence, John Loeser, Mushfiq Mobarak, Maria Jones, and Daniel Stein. "Learning from Self and Learning from Others: Experimental Evidence from Bangladesh," n.d.

Omotilewa, Oluwatoba J., Jacob Ricker-Gilbert, John Herbert Ainembabazi, and Gerald E. Shively. "Does Improved Storage Technology Promote Modern Input Use and Food Security? Evidence from a Randomized Trial in Uganda." Journal of Development Economics 135 (November 2018): 176–98. https://doi.org/10.1016/j.jdeveco.2018.07.006.

Suri, Tavneet. "Selection and Comparative Advantage in Technology Adoption." *Econometrica* 79, no. 1 (2011): 159–209. https://doi.org/10.3982/ECTA7749.

Tjernstrom, Emilia. "Learning from Others in Heterogeneous Environments," n.d.

Weiffen, Dorothee, Ghassan Baliki, and Tilman Brück. "Violent Conflict Moderates Food Security Impacts of Agricultural Asset Transfers in Syria: A Heterogeneity Analysis Using Machine Learning." HiCN, December 22, 2022. https://hicn.org/working-paper/381/.

3. Biofortified crop adoption

Biofortification uses different breeding techniques to increase the nutritional density of crops. Biofortification programs involve investments in crop breeding to target particular nutrient micronutrient deficiencies, distributing and encouraging the adoption of those varieties by producers and consumption by consumers. More consumption of biofortified crops decreases micronutrient deficiencies and improves health outcomes, particularly among women and children. Theory suggests that biofortification programs are a cost-effective way to increase micronutrient intake by smallholder farmers who produce and consume their own crops. However, it is difficult to reach rural farmers because they are less likely to purchase improved seed varieties or switch among improved seed varieties, as discussed in the preceding section. There is **high potential evidence** of the effectiveness of biofortified crop adoption on micronutrient status. However, there is limited evidence of how adoption impacts incomes, productivity, climate resilience, and broader nutritional outcomes.

Evidence from two small-scale studies in Uganda and Mozambique indicates that adopting biofortified crops can have positive effects on micronutrient intake, and evidence from India and Rwanda suggests that incorporating biofortified crops in school meals can improve nutritional outcomes. Bundled and payback models have encouraged adoption in sub-Saharan Africa, though there is limited evidence elsewhere. Ex-ante assessments suggest biofortification can be highly cost-effective, but there is limited ex-post evidence. Absent complementary interventions, the biofortification may be less effective. More research is needed to determine the impacts of adopting biofortified crops alone.

The delivery of biofortified crops can improve micronutrient intake and dietary diversity. For example, a biofortification intervention in Mozambique and Uganda doubled vitamin A intake among children (de Brauw et al., 2018). The program delivered vitamin A-enriched orange-fleshed sweet potato (OFSP) vines to farmers, as well as agronomic, marketing, and nutrition training. The nutrition component targeted women exclusively and modestly increased knowledge but did not influence behavior. Interventions that provide meals prepared with biofortified crops can also reduce micronutrient deficiencies, based on studies from India and Rwanda (Finkelstein et al., 2015; Haas et al., 2016). In cases where biofortified crops are intended specifically for children (e.g. protein enriched maize), complementary interventions to help households target fortified crops for consumption by children can significantly increase successful targeting but have no significant effects on anthropometric outcomes (Donato et al., 2020). Finally, other evidence from Mozambique suggests that promoting biofortified orange sweet potatoes had significant positive benefits by reducing diarrhea prevalence and vitamin A deficiency among women and children (Jones and de Brauw, 2015).

There is limited evidence of the impact of biofortification on incomes, productivity, and food security. It is possible that studies are powered to look at impacts on adoption, consumption, or nutrition, and larger samples would likely be needed to detect impacts on downstream economic outcomes, such as income and profits, which tend to be noisier measures. This is especially true because most biofortified seeds target specific deficiencies rather than aiming to improve yields or quality, which might have a first-order impact on agricultural income.

Adoption: Delivering biofortified crops in combination with training can have strong effects on seed adoption by farmers. Causal evidence is limited, but market access and information may be constraints to seed adoption (de Brauw et al., 2018).

Cost-effectiveness: Highly cost-effective when adoption is high. May have high fixed costs to develop and promote new varieties and lower marginal cost to deliver new varieties. Biofortification has been found to be "highly" cost-effective in several ex-ante assessments, but there is limited ex-post evidence (Meenakshi et al., 2010). One report found that the intervention in Uganda and Mozambique cost $15-20 per DALY averted, which would be considered highly cost-effective across any threshold (HarvestPlus, 2012). However, the estimate is reported by the implementer and provides limited information on how it was calculated. Data from an independent study shows that the intervention had an average cost of $86 per beneficiary in Mozambique and $56 in Uganda and that 70 percent of the cost disparity was due to the difference in diffusion rates (HarvestPlus, 2012). This indicates that costs could be further reduced by improving the design of dissemination strategies.

Context: Biofortified crops provide a steady and safe source of micronutrients in areas with more limited access to infrastructure and markets. As such, it may be a more suitable intervention in rural areas than in urban settings, where fortification and supplementation are alternative interventions. For example, biofortification has been found to be less cost-effective than supplementation and fortification in Latin America but potentially more cost-effective in sub-Saharan Africa and South Asia, which are significantly more rural regions (Meenakshi et al., 2010).

Biofortification can also be effective when implemented in institutional settings targeting children and women aged 15-49. Studies in India and Rwanda showed that meals prepared with biofortified crops (pearl millet and beans, respectively) and delivered in school cafeterias reduced iron deficiencies in adolescents aged 12 to 16 and women aged 18 to 27 (Finkelstein et al., 2015; Haas et al., 2016). However, the studies do not indicate whether fortification or supplementation would have been a more cost-effective intervention in those cases.

BIBLIOGRAPHY

Brauw, Alan de, Patrick Eozenou, Daniel O. Gilligan, Christine Hotz, Neha Kumar, and J. V. Meenakshi. "Biofortification, Crop Adoption and Health Information: Impact Pathways in Mozambique and Uganda." *American Journal of Agricultural Economics* 100, no. 3 (2018): 906–30. https://doi.org/10.1093/ajae/aay005.

Donato, Katherine, Margaret McConnell, Dan Han, Nilupa S Gunaratna, Masresha Tessema, Hugo De Groote, and Jessica Cohen. "Behavioural Insights to Support Increased Consumption of Quality Protein Maize by Young Children: A Cluster Randomised Trial in Ethiopia." *BMJ Global Health* 5, no. 12 (December 2020): e002705. https://doi.org/10.1136/bmjgh-2020-002705.

Finkelstein, Julia L., Saurabh Mehta, Shobha A. Udipi, Padmini S. Ghugre, Sarah V. Luna, Michael J. Wenger, Laura E. Murray-Kolb, Eric M. Przybyszewski, and Jere D. Haas. "A Randomized Trial of Iron-Biofortified Pearl Millet in School Children in India." *The Journal of Nutrition* 145, no. 7 (July 2015): 1576–81. https://doi.org/10.3945/jn.114.208009.

Haas, Jere D., Sarah V. Luna, Mercy G. Lung'aho, Michael J. Wenger, Laura E. Murray-Kolb, Stephen Beebe, Jean-Bosco Gahutu, and Ines M. Egli. "Consuming Iron Biofortified Beans Increases Iron Status in Rwandan Women after 128 Days in a Randomized Controlled Feeding Trial." *The Journal of Nutrition* 146, no. 8 (August 2016): 1586–92. https://doi.org/10.3945/jn.115.224741.

Harvest Plus. "Disseminating Orange-Fleshed Sweet Potato," 2010. https://assets.publishing.service.gov.uk/media/57a08a7a40f0b649740005fc/HarvestPlus_OFSP_Brief_web_English_2012.pdf.

Jones, Kelly M., and Alan de Brauw. "Using Agriculture to Improve Child Health: Promoting Orange Sweet Potatoes Reduces Diarrhea." *World Development* 74, no. C (2015): 15–24. https://ideas.repec.org//a/eee/wdevel/v74y2015icp15-24.html.

Meenakshi, J., Nancy Johnson, Victor Manyong, Hugo De Groote, Josyline Javelosa, David Yanggen, Firdousi Naher, Carolina González, James García, and Erika Meng. "How Cost-Effective Is Biofortification in Combating Micronutrient Malnutrition? An Ex Ante Assessment." *World Development* 38 (January 1, 2010): 64–75. https://doi.org/10.1016/j.worlddev.2009.03.014.

4. Irrigation

Irrigation interventions include both large-scale infrastructure projects and small-scale water management schemes. With reliable irrigation, farmers can cultivate a wider variety of crops throughout the year, increasing their food production and dietary diversity. Higher agricultural productivity could boost farmers' income and benefit the broader population, enhancing food security and resilience against droughts and irregular weather. There is **low evidence** of the impact of irrigation on agricultural productivity, income, climate resilience, and food and nutrition security outcomes for small-scale farmers. Large-scale irrigation can be profitable for farmers, but the benefits may be concentrated among landowners and depend on the farmer's location relative to the infrastructure. Small-scale irrigation can also increase net incomes for farmers and can improve climate resilience, but the evidence is limited and does not show significant effects on food security, consumption, or dietary diversity. Despite these potential gains, the adoption of irrigation technologies is low, potentially due to liquidity, information, and risk constraints.

Small-scale and drip irrigation systems are fed by rainwater or groundwater extracted with pumps. A recent intervention in Kenya suggests that providing farming households with hand pumps can increase revenues, though the effects are partly offset by reductions in off-farm earnings (Dyer and Shapiro, 2023). Effects on profits also depend on the way irrigation governance systems charge farmers to use the irrigation system. Experimental evidence in Bangladesh suggests that volumetric pricing can encourage farmers to use irrigation water in a more limited (and more profitable) way (Chakravorty et al. 2023) However, giving the option to voluntarily opt into a volumetric pricing scheme was not enough to invest in water-saving technology and adopt water conservation practices. The income effects of irrigation may become stronger in the longer term as farmers switch to fruit trees or other longer-duration crop choices (Aramburu et al. 2019). Irrigation may also lead households to diversify into livestock ownership and reduce food insecurity, particularly during the dry season, though the effects on the latter are mixed (Burney et al., 2010; Dyer and Shapiro, 2023).

Large-scale irrigation includes rainfed canals and dams. Evidence from Rwanda shows that hillside irrigation can be profitable for farmers, especially during dry seasons, though taking household labor into account at market wages offsets these effects - valuing labor at a fraction of the market wage to account for the probability of finding non-farm wage labor, would likely result in smaller but non-negative profit estimates (Jones et al., 2022). Irrigation can provide substantial productivity benefits for agricultural land-holding households, but few benefits tend to accrue to landless laborers or, in the case of dam construction, people located in further downstream regions for irrigation, suggesting adverse distributional impacts of dam construction (Asher et al., 2022). These adverse effects can intensify as dams amplify the effect of a negative rain shock in the districts upstream where the dam was constructed (Duflo and Pande, 2007).

Adoption: Despite more common use in South Asia and the MENA region, the adoption of irrigation is fairly low in sub-Saharan Africa, where it could have high expected returns (Jones et al. 2022). Smallholder farmers often face credit, information, and risk constraints that limit the adoption of complementary inputs

like seeds and fertilizer (Magruder, 2018). Large-scale investments may also not be fully exploited due to land and labor market failures. Access to irrigation alone is unlikely to surmount these barriers (Suri and Udry, 2022). Some firms provide irrigation as a service rather than requiring farmers to invest in assets themselves (Agriworks, n.d.). This could reduce friction and increase access, but there is no evidence to back this yet. Bundled services that address multiple constraints and models could also reduce credit market frictions and promote irrigation adoption (Jack et al., 2023).

Cost-effectiveness: Mixed evidence on large-scale irrigation systems, micro-pumps could be cost-effective depending on lifetime use. Public irrigation infrastructure requires long-term state investment, which is common in high-income settings. There is limited evidence on the cost-effectiveness of irrigation, but the available evidence indicates that the cost-effectiveness of irrigation systems is mixed. Specific irrigation systems were found to not be cost-effective in multiple contexts. In Bangladesh, the marginal cost of production of the pipe (AWD) was $1.66 - well above the level at which demand falls to zero (Chakravorty et al., 2023). In China, channel lining has a negative cost-effectiveness ratio due to the original investment and maintenance fees. Individual pumps for farmers have limited evidence of durability and continued use (Zou et al., 2013). Two studies indicated that investments in hand pumps and solar irrigation systems could pay off in two to five years (Dyer and Shapiro, 2023; Burney et al., 2010). Solar irrigation systems' payoff can be higher when considering the environmental benefits of avoiding carbon emissions per year compared with liquid-fuel alternatives. One study finds that solar pumps were approaching cost competitiveness with generator-powered systems in 2007 (Burney et al., 2010). Comparing four water-saving irrigation techniques in China, one cost-effectiveness analysis found that, when considering efficient responses to climate change, micro-irrigation techniques are more cost-efficient for mitigation and adaptation, including grain yield increase (Zou et al., 2013). Expansions in large-scale irrigation have high fixed costs and per-farmer variable costs. Enhancing the adoption of irrigation conditional on expansion in access could significantly improve the cost-effectiveness of public investment in irrigation, though there is no evidence to back this.

Context: In theory, expanding access to irrigation could result in a wide range of impacts for rural households. Irrigation may boost labor demand in dry seasons, when agricultural laborers may have fewer options in many contexts. This could have an anti-poverty effect, but existing evidence on this is mixed (Jones et al., 2022). Climatic conditions and conflict also likely play a role. In highly arid regions of countries like Mali, irrigation may provide a significant boost to productivity, but access to a reliable water source may limit the potential for scale. Institutional factors are also likely to play a role: What costs are charged to farmers to connect and maintain access to water sources for irrigation? How do regulators ensure upstream users don't overuse water and limit access for households further downstream?

Agriworks Uganda. "Home, Agriworks Uganda." Accessed June 7, 2024. https://www.agriworksug.com/.

Aramburu, Julián, Lucas Figal Garone, Alessandro Maffioli, Lina Salazar, and Cesar Augusto Lopez. "Direct and Spillover Effects of Agricultural Technology Adoption Programs: Experimental Evidence from the Dominican Republic." Working Paper. IDB Working Paper Series, 2019. https://doi.org/10.18235/0001742.

Asher, Sam, Alison Campion, Douglas Gollin, and Paul Novosad. "The Long-Run Development Impacts of Agricultural Productivity Gains: Evidence from Irrigation Canals in India," n.d.

Burney, Jennifer, Lennart Woltering, Marshall Burke, Rosamond Naylor, and Dov Pasternak. "Solar-Powered Drip Irrigation Enhances Food Security in the Sudano-Sahel." *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (February 2, 2010): 1848–53. https://doi.org/10.1073/pnas.0909678107.

Chakravorty, Ujjayant, Manzoor H. Dar, and Kyle Emerick. "Inefficient Water Pricing and Incentives for Conservation." *American Economic Journal: Applied Economics* 15, no. 1 (January 2023): 319–50. https://doi.org/10.1257/app.20210011.

Duflo, Esther, and Rohini Pande. "Dams*." *The Quarterly Journal of Economics* 122, no. 2 (May 1, 2007): 601–46. https://doi.org/10.1162/qjec.122.2.601.

Dyer, Julian, and Jeremy Shapiro. "The Benefits of Small-Scale Irrigation Pumps for Kenyan Farmers." VoxDev, 2023. https://voxdev.org/topic/agriculture/benefits-small-scale-irrigation-pumps-kenyan-farmers.

Jack, William, Michael Kremer, Joost de Laat, and Tavneet Suri. "Credit Access, Selection, and Incentives in a Market for Asset-Collateralized Loans: Evidence From Kenya." *The Review of Economic Studies* 90, no. 6 (November 1, 2023): 3153–85. https://doi.org/10.1093/restud/rdad026.

Jones, Maria, Florence Kondylis, John Loeser, and Jeremy Magruder. "Factor Market Failures and the Adoption of Irrigation in Rwanda." *American Economic Review* 112, no. 7 (July 2022): 2316–52. https://doi.org/10.1257/aer.20210059.

Magruder, Jeremy R. "An Assessment of Experimental Evidence on Agricultural Technology Adoption in Developing Countries." *Annual Review of Resource Economics* 10, no. Volume 10, 2018 (October 5, 2018): 299–316. https://doi.org/10.1146/annurev-resource-100517-023202.

Suri, Tavneet, and Christopher Udry. "Agricultural Technology in Africa." *Journal of Economic Perspectives* 36, no. 1 (February 2022): 33–56. https://doi.org/10.1257/jep.36.1.33.

Zou, Xiaoxia, Yu'e Li, Kuo Li, Roger Cremades, Qingzhu Gao, Yunfan Wan, and Xiaobo Qin. "Greenhouse Gas Emissions from Agricultural Irrigation in China." *Mitigation and Adaptation Strategies for Global Change* 20 (February 1, 2013): 295–315. https://doi.org/10.1007/s11027-013-9492-9.

5. Fertilizer and inputs access and adoption

Different interventions aim to optimize access to and adoption of fertilizer and other agricultural inputs. When appropriate for the context and used in the right amounts at the right time, fertilizer and other inputs can increase yields, reduce losses, improve quality, and are often a potentially profitable investment for farmers. There is **mixed evidence** for the cost-effectiveness of targeted interventions to optimize fertilizer and input access and adoption to improve agricultural productivity and income while limiting environmental externalities. Despite this, adoption remains consistently low in Sub-Saharan Africa, and overuse of fertilizer is a consistent issue in South Asia, Latin America, and the Caribbean (FAO, 2022). Fertilizer use in the MENA region tends to be moderate. Improving access to fertilizers, seeds, pesticides, and other agricultural inputs has the potential to boost yields, benefiting farmers by enhancing food security and increasing food availability within communities. There is a lack of evidence on nutrition, likely because nutrition status is not often a target outcome for this category of interventions.

Traditional subsidy programs implemented by many governments provide blanket subsidies to lower the cost of inputs. These methods are commonly used to promote fertilizer adoption but are often inefficiently designed. As a result, these may encourage the overuse of fertilizer, with negative environmental and productivity consequences, or result in subsidies being largely captured by farmers who would otherwise already use fertilizer. A 2013 review indicates that the cost of input subsidy programs often outweigh the benefits but notes that they are often politically popular, particularly in some parts of Africa, so it may not be straightforward to implement large-scale changes (Jayne and Rashid, 2013). A satellite-based yield analysis of farm inputs subsidies in Malawi found that gains from wide-scale fertilizer distribution may be lower than estimates provided by public-sector sources (Messina et al., 2017) However, targeted vouchers can induce experimentation and reduce inefficient subsidization, improving cost-effectiveness and the efficient use of public resources. These programs are sometimes supplemented with educational components, such as demonstration plots or personalized recommendations (Bird et al. 2022; Abate et al. 2018).

Targeted vouchers can be fairly effective at improving fertilizer use and agricultural productivity by subsidizing learning without providing large-scale or long-term distortions to the market. For example, giving temporary vouchers to farmers with high potential gains led to large increases in yields and consumption in Mozambique (Carter et al. 2021). It also generated spillovers that increased technology adoption, yields, and knowledge among farmers' social networks (Carter et al., 2021). Other targeted interventions that have led to higher yields and revenues include providing farmers with access to bundled interventions, demonstration plots, inventory credit paired with input supply shops, and brief instructional sessions on the correct application of fertilizer (Abate et al., 2018; Bird et al., 2022; Pender et al., 2008; Beaman et al., 2013). In contrast, evidence from Haiti suggests that a fertilizer subsidy program had no impact on yields and decreased fertilizer usage (Gignoux et al., 2022). Evidence from Kenya also shows that a small, time-limited discount on fertilizer at harvest time may be much more cost-effective than traditional subsidy models (Duflo et al., 2011).

However, there is mixed evidence on the effects of these interventions on income. Measuring the income effects of agricultural interventions is often challenging due to compounding imprecision in measurement. Evidence from an intervention targeting female farmers in Mali shows no significant effects on income despite increased productivity (Beaman et al., 2013). This suggests that the impact of fertilizer on profits may be small compared to other sources of variation, which can affect farmers' ability to learn about the returns to fertilizer and their decision to readopt. This is consistent with evidence from Malawi showing that the productivity effects of fertilizer subsidies may dissipate over time in the absence of interventions that increase soil fertility (Ricker-Gilbert and Jayne, 2016).

There is also no evidence of the effects of increased fertilizer and input access and adoption on food security or dietary diversity. However, there is non-experimental evidence that the provision of other agricultural inputs beyond fertilizer has positive impacts on food security, particularly in fragile and conflict-affected contexts. In Syria, an agricultural asset transfer program (assets included vegetable seeds, agricultural tools, drip irrigation kits, etc.) had significant positive effects on food security, and agricultural and livestock interventions (including vegetable toolkits and seedlings, beekeeping support, the distribution of poultry, etc.) had long-term positive impacts on food consumption scores, dietary diversity scores, and reduced coping strategy index (RCSI) scores (Weiffen et al., 2022; Kayaoglu et al., 2023). Evidence from Niger suggests that combining nutrition-specific assistance (directly treating malnutrition) and nutrition-sensitive assistance (addressing the underlying causes of malnutrition via food aid, clean water provision, crop diversification, etc.) has positive impacts on nutritional outcomes, whereas nutrition-specific assistance alone does not (Brück et al., 2019).

Adoption: Farmers face a variety of constraints to adopting fertilizer and other complementary inputs, including issues of liquidity and credit access, risk, and information. Beliefs about the low quality of fertilizers are widespread and often stem from observed inconsistent outcomes (Hoel et al. 2022). A growing set of programs have strong evidence of effectiveness in increasing farmer adoption of fertilizer and complementary inputs. Vouchers are an effective tool to increase adoption, especially given the spillover and longer-run benefits, as are time-limited discounts (Carter et al., 2021; Duflo et al., 2011). Bundling together program elements that address credit, risk, and information constraints improves both fertilizer adoption and correct use (Adong et al., 2020; Deutschmann et al., 2023). Concerns about quality may limit the adoption of fertilizer and other inputs, although most evidence from lab-based assessments of quality suggests the problems are less severe than the popular perception (Bold et al., 2017; Michelson et al., 2022).

Evidence on the correct adoption of complementary inputs, including pesticides and bio-control products, is less widespread. For the biocontrol product Aflasafe, there is consistent evidence from Senegal and Kenya that providing a food safety premium and addressing credit and information constraints can increase adoption significantly (Deutschmann et al., 2023; Hoffman et al., 2022). For reducing pesticide overuse, evidence from Vietnam suggests training buyers and intermediaries together is much more effective than training either alone (Park et al., 2022).

Cost-effectiveness: There is some evidence of cost-effectiveness, but it depends on the length of subsidies and market prices of fertilizer and inputs. Improving access to fertilizer and inputs can be cost-effective, but the evidence is still limited. Mozambique's input subsidy program has been found to be highly cost-effective, including when fertilizer is valued at market prices, leading to a roughly ten-fold increase in the benefit-cost ratio from 1.8 to 19.8. over three years (Carter et al., 2021). In settings where fertilizer use is widespread, leaf color charts (LCCs) can optimize fertilizer use and improve profits for farmers (Islam and Beg, 2021). The introduction of LCCs in Bangladesh had high returns: every dollar spent yielded $2.8 as a result of fertilizer use reductions over the following three seasons (Islam and Beg, 2021). Reduction in the use of urea translates into an overall environmental damage reduction of US$0.32 per farmer over one season, or US$11 million (0.3 million tons) in CO2 emissions (Islam and Beg, 2021).

Context: The benefits of fertilizer depend on the existing soil quality, relative prices of fertilizer and seeds, and the agricultural potential of the local soil (Chamberlin et al., 2021; Kassie et al., 2010). Blanket subsidies typically lead to fertilizer overuse, with negative environmental and productivity consequences. The direct benefits of non-targeted subsidies may also disproportionately benefit wealthier farmers. This may also be the case with targeted programs that target farmers with larger expected gains. Interventions targeting vulnerable groups have only been tested in limited settings (Beaman et al., 2013).

Abate, Gashaw Tadesse, Tanguy Bernard, Alan de Brauw, and Nicholas Minot. "The Impact of the Use of New Technologies on Farmers' Wheat Yield in Ethiopia: Evidence from a Randomized Control Trial." *Agricultural Economics* 49, no. 4 (2018): 409–21. https://doi.org/10.1111/agec.12425.

Adong, Annet, James Tinker, David Levine, Swaibu Mbowa, and Tony Odokonyero. "Encouraging Fertilizer Adoption through Risk Free Sales Offer: A Randomized Control Trial in Uganda." *World Development Perspectives* 19 (September 1, 2020): 100230. https://doi.org/10.1016/j.wdp.2020.100230.

Beaman, Lori, Dean Karlan, Bram Thuysbaert, and Christopher Udry. "Profitability of Fertilizer: Experimental Evidence from Female Rice Farmers in Mali." *American Economic Review* 103, no. 3 (May 2013): 381–86. https://doi.org/10.1257/aer.103.3.381.

Bird, Samuel S., Michael R Carter, Travis J. Lybbert, Mary Mathenge, Timothy Njagi, and Emilia Tjernstrom. "Filling a Niche? The Maize Productivity Impacts of Adaptive Breeding by a Local Seed Company in Kenya." Google Docs, 2022. https://drive.google.com/file/d/15LGHo_I-es5WgXbjiwKbg3xij7MSX0F7/view?usp=share_link&usp=embed_facebook.

Bold, Tessa, Kayuki C. Kaizzi, Jakob Svensson, and David Yanagizawa-Drott. "Lemon Technologies and Adoption: Measurement, Theory and Evidence from Agricultural Markets in Uganda*." *The Quarterly Journal of Economics* 132, no. 3 (August 1, 2017): 1055–1100. https://doi.org/10.1093/qje/qjx009.

Brück, Tilman, Oscar Mauricio Díaz Botía, Neil T. N. Ferguson, Jérôme Ouédraogo, and Zacharias Ziegelhöfer. "Assets for Alimentation? The Nutritional Impact of Assets-Based Programming in Niger." *The Journal of Development Studies* 55, no. sup1 (December 13, 2019): 55–74. https://doi.org/10.1080/00220388.2019.1687876.

Carter, Michael, Rachid Laajaj, and Dean Yang. "Subsidies and the African Green Revolution: Direct Effects and Social Network Spillovers of Randomized Input Subsidies in Mozambique." *American Economic Journal: Applied Economics* 13, no. 2 (April 2021): 206–29. https://doi.org/10.1257/app.20190396.

Chamberlin, Jordan, T. S. Jayne, and Sieglinde Snapp. "The Role of Active Soil Carbon in Influencing the Profitability of Fertilizer Use: Empirical Evidence from Smallholder Maize Plots in Tanzania." *Land Degradation & Development* 32, no. 9 (2021): 2681–94. https://doi.org/10.1002/ldr.3940.

Deutschmann, Joshua W, Tanguy Bernard, and Ouambi Yameogo. "Contracting and Quality Upgrading: Evidence from an Experiment in Senegal," 2023.

Deutschmann, Joshua W., Maya Duru, Kim Siegal, and Emilia Tjernstrom. "Relaxing Multiple Agricultural Productivity Constraints at Scale." SSRN Scholarly Paper. Rochester, NY, June 15, 2023. https://doi.org/10.2139/ssrn.4479905.

Duflo, Esther, Michael Kremer, and Jonathan Robinson. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." *American Economic Review* 101, no. 6 (October 2011): 2350–90. https://doi.org/10.1257/aer.101.6.2350.

FAO. "Fertilizer consumption (kilograms per hectare of arable land) - Middle East & North Africa, Latin America & Caribbean, Sub-Saharan Africa, South Asia, Europe & Central Asia (excluding high income)". 2022. https://data.worldbank.org/indicator/AG.CON.FERT.ZS?end=2021&locations=ZQ-ZJ-ZG-8S-7E&start=1961&view=chart

Gignoux, Jérémie, Karen Macours, Daniel Stein, and Kelsey Wright. "Input Subsidies, Credit Constraints, and Expectations of Future Transfers: Evidence from Haiti." *American Journal of Agricultural Economics* 105, no. 3 (2023): 809–35. https://doi.org/10.1111/ajae.12337.

Hoel, Jessica B., Hope Michelson, Ben Norton, and Victor Manyong. "Misattribution Prevents Learning." *American Journal of Agricultural Economics* n/a, no. n/a. Accessed June 7, 2024. https://doi.org/10.1111/ajae.12466.

Hoffmann, Vivian, Sarah Kariuki, Janneke Pieters, and Mark Treurniet. "Upside Risk, Consumption Value, and Market Returns to Food Safety." *American Journal of Agricultural Economics* 105, no. 3 (2023): 914–39. https://doi.org/10.1111/ajae.12349.

IFPRI. "Impacts of Inventory Credit, Input Supply Shops, and Fertilizer Microdosing in the Drylands of Niger | IFPRI : International Food Policy Research Institute." Accessed June 7, 2024. https://www.ifpri.org/publication/impacts-inventory-credit-input-supply-shops-and-fertilizer-microdosing-drylands-niger.

Islam, Mahnaz, and Sabrin Beg. "Rule-of-Thumb Instructions to Improve Fertilizer Management: Experimental Evidence from Bangladesh." *Economic Development and Cultural Change* 70, no. 1 (October 2021): 237–81. https://doi.org/10.1086/711174.

Jayne, T.s., and Shahidur Rashid. "Input Subsidy Programs in Sub-Saharan Africa: A Synthesis of Recent Evidence." *Agricultural Economics* 44, no. 6 (2013): 547–62. https://doi.org/10.1111/agec.12073.

Kassie, Menale, Precious Zikhali, John Pender, and Gunnar Köhlin. "The Economics of Sustainable Land Management Practices in the Ethiopian Highlands." *Journal of Agricultural Economics* 61, no. 3 (2010): 605–27. https://doi.org/10.1111/j.1477-9552.2010.00263.x.

Messina, Joseph P., Brad G. Peter, and Sieglinde S. Snapp. "Re-Evaluating the Malawian Farm Input Subsidy Programme." *Nature Plants* 3, no. 4 (March 6, 2017): 1–9. https://doi.org/10.1038/nplants.2017.13.

Michelson, Hope, Sydney Gourlay, and Philip Wollburg. *Non-Labor Input Quality and Small Farms in Sub-Saharan Africa: A Review*. Policy Research Working Papers. The World Bank, 2022. https://doi.org/10.1596/1813-9450-10092.

Park, Sangyoon, Zhaoneng Yuan, and Hongsong Zhang. "Technology Training, Buyer-Supplier Relationship, and Quality Upgrading in an Agricultural Supply Chain." *The Review of Economics and Statistics*, May 29, 2023, 1–46. https://doi.org/10.1162/rest_a_01341.

Pender, John, Tahirou Abdoulaye, Jupiter Ndjeunga, Bruno Gerard, and Edward Kato. "Impacts Of Inventory Credit, Input Supply Shops, and Fertilizer Microdosing in the Drylands of Niger." *IFPRI*, 2008.

Ricker-Gilbert, Jacob, and T. S. Jayne. "Estimating the Enduring Effects of Fertiliser Subsidies on Commercial Fertiliser Demand and Maize Production: Panel Data Evidence from Malawi." *Journal of Agricultural Economics* 68, no. 1 (2017): 70–97. https://doi.org/10.1111/1477-9552.12161.

Weiffen, Dorothee, Ghassan Baliki, and Tilman Brück. "Violent Conflict Moderates Food Security Impacts of Agricultural Asset Transfers in Syria: A Heterogeneity Analysis Using Machine Learning." HiCN, December 22, 2022. https://hicn.org/working-paper/381/.

World Bank. "World Bank Open Data." World Bank Open Data. Accessed June 7, 2024. https://data.worldbank.org.

6. Traditional agricultural extension

Traditional agricultural extension programs are large-scale public sector initiatives to improve agricultural outcomes through providing farmers with information, training, and technologies. Agricultural extension services facilitate the dissemination of knowledge and best practices in farming techniques. By providing tailored support and training, farmers can enhance their agricultural productivity and resilience to environmental challenges. Extension programs vary widely in scope and scale but typically involve extension agents who visit farmers and provide information and training, subsidize agricultural inputs, and/or facilitate credit and market access. Extension has traditionally been a core development program and received significant funding. There is **low evidence** of the impacts of traditional, public extension programs on agricultural productivity, income, climate resilience, and food and nutrition security. Earlier reports have described mixed evidence of the impact and internal rates of return of extension investments (Anderson and Feder, 2007). They highlight the quality of the data as the main challenge to accurately estimate the causal effect of this type of public investment. There is also a rising number of private providers (including NGOs) that deliver a range of advisory services with some documented success; these models fall outside the scope of this review and are covered in later sections. Examples of these providers include One Acre Fund, myAgro, Apollo Agriculture, and Babban Gona.

Considering the causal evidence available, government-led extension programs focused mainly on maize smallholder farmers have been found to have disappointing effects on productivity based on an earlier wave of studies (Gautam, 2000; Swanson et al., 1998). This may result from a disproportionate focus on maximizing farmers' yields rather than profits (Duflo et al., 2008). More recent evaluations have found similar trends, even for less traditional extension models. The National Agricultural Advisory Services (NAADS) program in Uganda, for example, promotes the creation of farmer groups where enrolled farmers have access to demonstration sites and advisory services from trained community facilitators. NAADS has been found to have mixed and weak effects across a range of productivity and revenue outcomes (Benin et al., 2012). Nonetheless, more elaborate extension programs that bundle advisory services with input and market access seem more promising. One example is Ethiopia's Wheat Initiative, which has been found to have positive effects on yields and the adoption of certified seeds and fertilizer (Abate et al., 2018). It is important to keep in mind that these studies have considered different ways of conveying, teaching, and disseminating extension information and services, but more evidence should be collected on the effectiveness of the information provided and also the means to deliver information.

While not a focus of this review, private sector-led extension models can provide useful insights into the design of large-scale public programs. For example, a large-scale extension program implemented by a nonprofit in Uganda had large positive effects on production, savings, income, food security, and the household's ability to deal with shocks (Pan et al., 2018). The program provided female farmers with training and subsidized inputs and increased per capita household food consumption expenditure by 11.6% among farmers in eligible villages. Although there was a modest reduction in consumption during shocks like droughts or floods, farmers were less likely to sell their assets, a coping strategy that often comes at the cost of future food insecurity. This study proposes female empowerment and the resulting reallocation of resources as a potential mechanism to explain these results.

Adoption: One of the main barriers to the effectiveness of extension programs is scale. In many countries, the ratio of farmers to extension agents exceeds 1,000 to 1, severely limiting their reach (Davis et al., 2010). This has led researchers and practitioners to test innovative delivery mechanisms to decentralize extension services. For example, incorporating social learning and leveraging existing social networks can be an effective strategy to influence learning and technology adoption. In Malawi, providing lead farmers with a small incentive to learn about new technologies and promote them among their peers was more effective than dissemination through government agents (BenYishay and Mobarak, 2019; Beaman et al., 2021). The adoption of these sustainable agriculture practices, like pit planting and composting, led to yield gains. Model farmer demonstrations in Uganda incentivized the adoption of improved sustainable practices like the use of manure, intercropping, crop rotation, and irrigation that required low upfront investment (Pan et. al., 2018). Learning-by-doing models also have the potential to amplify extension services through contact farmers (CFs). However, evidence from Mozambique shows that training CFs alone may be insufficient to accelerate technology diffusion among peer farmers (Kondylis and Mueller, 2013).

The use of digital tools is also gaining ground as a complement or substitute for in-person services (see separate review on ICT-based extension services). Another important challenge is the monitoring of extension agents to ensure that all program components are effectively delivered (Abate et al., 2018). Equipping agricultural extension agents with GPS-enabled cell phones can improve agent efficiency and farmer satisfaction by allowing supervisors to monitor agents (Dal Bó et al., 2021).

Cost-effectiveness: Mixed evidence of cost-effectiveness for traditional agricultural extension in low-income settings. Cost-effectiveness could improve if coupled with training and diffusion strategies or digital extension services. There is limited evidence on the cost-effectiveness of extension services. In Uganda, an initial evaluation of NAADS found the program to be cost-effective, with a rate of return of 8 to 49 percent (Benin et al., 2010). However, a follow-up study was unable to isolate the effects of the program on access to non-NAADS extension services (Benin et al., 2012). Leveraging social networks is a promising approach to increase the cost-effectiveness of extension services, though program design remains a determinant factor (BenYishay and Mobarak, 2019). ICTs may also reduce the marginal cost of reaching additional farmers, and demand-driven approaches, such as the Plantwise approach in Kenya, may reduce costs by delivering information to farmers facing a specific issue (Bonilla et al., 2023).

Context: Traditional agricultural extension has been a critical component of most of the rural development plans. Earlier studies provided valuable insights into the complexities of implementing agricultural extension programs and emphasized the need to carefully consider the type of extension program to implement (Anderson and Feder, 2007). Context plays a key role in the effectiveness of traditional extension programs. Extension agents must travel large distances to visit farmers, which may impact farmers in more remote locations or conflict-affected settings. Farmers also respond differently to messages depending on who delivers them, as explained by the social learning literature (BenYishay and Mobarak, 2019). The timing of visits or messaging may also play a role in learning and technology adoption, based on ongoing research in India. Finally, heterogeneity in farming conditions in a given area may also influence the effectiveness of decentralized extension models. Evidence from Mozambique shows that social learning is most effective among farmers who grow similar crops (Kondylis and Mueller, 2013). Kenya's Plantwise clinics require farmers to travel to the extension agent, where they are provided with diagnoses and recommendations for disease management. The demand-driven approach led to improved farm management and maize yields.

Abate, Gashaw Tadesse, Tanguy Bernard, Alan de Brauw, and Nicholas Minot. "The Impact of the Use of New Technologies on Farmers' Wheat Yield in Ethiopia: Evidence from a Randomized Control Trial." *Agricultural Economics* 49, no. 4 (2018): 409–21. https://doi.org/10.1111/agec.12425.

Anderson, Jock, and Gershon Feder. "Chapter 44 Agricultural Extension." *Handbook of Agricultural Economics* 3 (December 31, 2007): 2343–78. https://doi.org/10.1016/S1574-0072(06)03044-1.

Apollo Agriculture. "Apollo Agriculture." Apollo Agriculture. Accessed June 7, 2024. https://www.apolloagriculture.com.

Babban Gona. "Babban Gona | Better Your Life." Babban Gona. Accessed June 7, 2024. https://babbangona.com/.

Beaman, Lori, Ariel BenYishay, Jeremy Magruder, and Ahmed Mushfiq Mobarak. "Can Network Theory-Based Targeting Increase Technology Adoption?" *American Economic Review* 111, no. 6 (June 2021): 1918–43. https://doi.org/10.1257/aer.20200295.

Benin, Samuel, Ephraim Nkonya, Geresom Okecho, Joseé Randriamamonjy, Edward Kato, Geofrey Lubade, and Miriam Kyotalimye. "Impact of the National Agricultural Advisory Services (Naads) Program of Uganda: Considering Different Levels of Likely Contamination with the Treatment." *American Journal of Agricultural Economics* 94, no. 2 (2012): 386–92. https://www.jstor.org/stable/41331263.

———. "Returns to Spending on Agricultural Extension: The Case of the National Agricultural Advisory Services (NAADS) Program of Uganda†." *Agricultural Economics* 42, no. 2 (2011): 249–67. https://doi.org/10.1111/j.1574-0862.2010.00512.x.

BenYishay, Ariel, and A Mushfiq Mobarak. "Social Learning and Incentives for Experimentation and Communication." *The Review of Economic Studies* 86, no. 3 (May 1, 2019): 976–1009. https://doi.org/10.1093/restud/rdy039.

Bonilla, Juan D, Andrea Coombes, Dannie Romney, and Paul C Winters. "Changing the Logic in Agricultural Extension: Evidence from a Demand-Driven Extension Programme in Kenya," 2023. https://www.tandfonline.com/doi/epdf/10.1080/19439342.2023.2181848?needAccess=true&role=button.

Dal Bó, Ernesto, Frederico Finan, Nicholas Y. Li, and Laura Schechter. "Information Technology and Government Decentralization: Experimental Evidence From Paraguay." *Econometrica* 89, no. 2 (2021): 677–701. https://doi.org/10.3982/ECTA17497.

Davis, Kristin, Burton Swanson, and David Amudavi. "In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendations for Improvement," n.d.

Duflo, Esther, Michael Kremer, and Jonathan Robinson. "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya." *American Economic Review* 98, no. 2 (May 2008): 482–88. https://doi.org/10.1257/aer.98.2.482.

Gautam,Madhur. "Agricultural Extension : The Kenya Experience - an Impact Evaluation." Text/HTML. World Bank. Accessed June 7, 2024. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/753941468254951667/Agricultural-extension-the-Kenya-experience-an-impact-evaluation.

Kondylis, Florence, and Valerie Mueller. "Seeing Is Believing? Evidence from a Demonstration Plot Experiment in Mozambique," November 12, 2013.

MyAgro. “MyAgro.” Accessed June 7, 2024. https://www.myagro.org/.

One Acre Fund. “One Acre Fund.” One Acre Fund, April 22, 2024. https://oneacrefund.org/.

Pan, Yao, Stephen C Smith, and Munshi Sulaiman. “Agricultural Extension and Technology Adoption for Food Security: Evidence from Uganda.” *American Journal of Agricultural Economics* 100, no. 4 (2018): 1012–31. https://doi.org/10.1093/ajae/aay012.

Swanson, Burton E, Robert P. Bentz, and Andrew J. Sofranko. “Improving Agricultural Extension A Reference Manual,” 1998. https://www.farm-d.org/app/uploads/2013/06/Improving-AgEx.-FAO.pdf.

7. Training and information diffusion

Farmers require information to adopt improved management techniques and inputs. Besides government extension services, where experts are continually helping and giving advice to farmers in the field with specific skills, researchers and practitioners have explored means to train farmers on improved agricultural practices, including proper use of seeds and fertilizer, use of complementary techniques like demi-lunes for rainwater harvesting, and strategies for managing harvests to maintain quality and minimize postharvest losses. Through training, farmers acquire the necessary skills to effectively utilize emerging technologies. The social network approach facilitates information sharing among farmers, thus enhancing the potential for widespread adoption of yield-enhancing technologies that improve farmers' income and food security. Taken together, there is **good evidence** of the effectiveness of providing farmers with training to achieve agricultural, climate, food, and nutrition security outcomes. However, it is important also to consider how the degree to which the information is timely and tailored can affect their success.

Training and providing farmers with targeted information could be an effective way to improve agricultural outcomes. A large-scale program implemented by a nonprofit in Uganda had large positive effects on savings, income, and food security (Pan et al., 2018). The program provided female farmers with training and subsidized inputs and increased per capita household food consumption expenditure by 11.6% among farmers in eligible villages. Similarly, an intervention in Ethiopia that provided households in maize-growing areas with site-specific fertilizer recommendations had significant effects on the appropriate use of fertilizer, yields, and profits, though it found no evidence of improvements in household consumption (Ayalew et al., 2022). When provided in addition to recommendations, crop insurance showed no additional benefits in this context. The targeted aspect of these interventions may be key to shifting farmer behavior. However, the provision of tailored information may not be sufficient in the absence of complementary interventions.

However, in certain situations, training or targeted recommendations may have limited impact unless supplemented by additional interventions. Evidence from maize farmers in Mexico shows that recommendation specificity had little effect on short and longer-term outcomes if not accompanied by extension services and in-kind grants to get inputs (Corral et al., 2022). Once farmers adopted these recommendations, they experienced an increase in yields despite the negative effects of a drought season and a voluntary reduction in urea use, which translated into a reduction of CO2 equivalent emissions. Pairing fertilizer recommendations with input vouchers produced a large effect on adoption and maize yields, and when facing a drought in Tanzania during the study, farmers were able to avoid a decline in yield (Harou et al., 2022). Similarly, only adjusting training to farmer needs did not improve the effects of a contact farmer intervention in the dairy sector in Uganda (Behaghel et al., 2020). In Bangladesh, a program that combined support to input retailers with agri-fests that provided standard information sessions and consultations found no evidence of higher yields, as most farmers did not follow recommended seeding rates (De Brauw et al., 2020). Other small-scale programs in Bangladesh find that intensive training in home garden cultivation has durable effects when targeting women (Baliki et al., 2022).

Adoption: The lack of effective channels to disseminate information is a significant barrier to the adoption of improved agricultural practices (Aker and Jack, 2021). Incorporating social learning can be an effective

strategy to influence information diffusion. In India, peer-to-peer learning, as opposed to mentor-led sessions, facilitated collective learning and discussions of new technologies, significantly increasing the adoption rates (Dar and Emerick, 2021). Another peer-to-peer dissemination program in Bangladesh, matching trained farmers with farmers who list them as role models, induced the adoption of technology and resulted in higher crop yields and profits among participants, with no significant increase in input and labor costs (Fafchamps et al., 2021).

In Malawi, providing farmers with a small incentive to learn about new technologies and promote them among their peers was more effective than dissemination through government agents (Benyishay and Mobarak, 2019). However, farmers may be reluctant to disseminate information they do not know to be trustworthy. In those cases, leveraging tools that are transparent, credible, simple to use, and easy to explain can be effective - as shown by an intervention in Kenya that provided a simple kitchen spoon (painted in blue) to measure out how much fertilizer to use, with promising results for technology diffusion (Chandrasekhar et al., 2022).

In Indonesia, seaweed producers only adopted recommendations when the intervention was accompanied by experiment summaries of the optimal decisions (Hanna et al., 2014). Similarly, soil health cards (SHCs) tailored to specific soil conditions had no effect on fertilizer application, and farmers with stronger or less dispersed beliefs had a lower willingness to pay for SHCs, based on evidence from India (Fishman et al., 2019). Learning-by-doing models also have the potential to amplify information diffusion but may not occur spontaneously in all contexts - see evidence from Kenya and Mozambique (Chandrasekhar et al., 2022; Kondylis et al., 2017).

In Mozambique, the increase in adoption of sustainable land management practices by contact farmers and its associated positive effects in labor savings and yields during dry conditions were not enough to increase adoption among other farmers in the community; perception of high adoption costs and credibility in the source of information played an important role in peer adoption (Kondylis et al., 2017). Finally, sustaining technology adoption can be challenging in the absence of recurring visits or messaging. Leaf color charts (LCCs), a simple tool that indicates whether a crop requires fertilizer, have been shown to optimize fertilizer use and reduce costs for farmers (Islam and Beg, 2021).

Cost-effectiveness: Highly cost-effective for some types of information diffusion - such as leveraging social networks and disseminating leaf color charts. Interventions that facilitate training and information diffusion can be cost-effective, but there is limited data and significant variation across models. In some cases, information alone may be the most cost-effective way to promote technology adoption. Evidence from Ethiopia and Nigeria shows that complementing training programs with crop insurance or cash transfers may have no additional benefits over training alone (Ayalew et al., 2022; Aker and Jack, 2021).

Evidence from Uganda and Cote d'Ivoire also suggests that training models that take advantage of social networks can be more cost-effective than aiming to train all farmers directly (Vasilaky and Leonard, 2018; Takahashi et al., 2019). For example, a peer-to-peer dissemination strategy training role model farmers resulted in social returns in excess of 100 percent (Fafchamps et al., 2021). A similar experiment, a contact farmer model that succeeded in transmitting information to non-trained farmers, resulted in a net gain of $454 per village per year. However, information may not always reach non-trained farmers (Behaghel, 2020). However, in other cases, simple technologies can effectively complement training to achieve sustained effects. For example, each dollar spent on delivering LCCs in Bangladesh produced a return of $2.8 due to fertilizer savings over three seasons and environmental benefits (Islam and Beg, 2021).

Context: Understanding complementarities between information, the complexity of the technology, past experience, market imperfections, and other constraints is critical for success. In Ethiopia, information alone

was sufficient to change practices, with little additional impact from cash or insurance (Ayalew et al., 2022). Although evidence from Niger suggests a similar outcome, the total adoption of demi-lunes, a technology that helps with land degradation and soil fertility, was higher in more degraded land and among farmers with previous experience (Aker and Jack, 2021). In Tanzania, however, site-specific fertilizer recommendations were only effective when paired with an input subsidy (Harou et al., 2022).

Market structures also play a relevant role in the results of training programs. In the context of imperfect input markets, varying the proportion of farmers trained in Rwanda resulted in negative spillovers that may outweigh any gains of the training (Duflo et al., 2023). For example, in regions where more farmers received training, farmers who did not participate in the program had a decrease in their yields. Importantly, the type of technology being promoted can significantly impact the effectiveness and cost-effectiveness of an intervention. Along those lines, targeting information on farming conditions and farmers' needs seems to play a big role. However, in contexts with a limited presence of extension services, site-specific data may not be readily available. While traditional government extension–as discussed in a separate review–is a primary vehicle for providing farmers with information and training, the interventions discussed here are typically provided by private companies or nonprofit organizations.

Aker, Jenny C., and Kelsey Jack. "Harvesting the Rain: The Adoption of Environmental Technologies in the Sahel." Working Paper. Working Paper Series. National Bureau of Economic Research, November 2021. https://doi.org/10.3386/w29518.

Ayalew, Hailemariam, Jordan Chamberlin, and Carol Newman. "Site-Specific Agronomic Information and Technology Adoption: A Field Experiment from Ethiopia." *Journal of Development Economics* 156 (May 1, 2022): 102788. https://doi.org/10.1016/j.jdeveco.2021.102788.

Baliki, Ghassan, Pepijn Schreinemachers, Tilman Brück, and Nasir Md. Uddin. "Impacts of a Home Garden Intervention in Bangladesh after One, Three and Six Years." *Agriculture & Food Security* 11, no. 1 (September 10, 2022): 48. https://doi.org/10.1186/s40066-022-00388-z.

Behagel, Luc, Jérémie Gignoux, and Karen Macours. "Social Learning in Agriculture: Does Smallholder Heterogeneity Impede Technology Diffusion in Sub-Saharan Africa?," 2020. https://www.parisschoolofeconomics.com/behaghel-luc/FTpaper.pdf.

BenYishay, Ariel, and A Mushfiq Mobarak. "Social Learning and Incentives for Experimentation and Communication." *The Review of Economic Studies* 86, no. 3 (May 1, 2019): 976–1009. https://doi.org/10.1093/restud/rdy039.

Brauw, Alan de, Berber Kramer, and Mike Murphy. "Yielding Profits? Low Adoption of an Improved Mung Bean Seed Variety in Southern Bangladesh." SSRN Scholarly Paper. Rochester, NY, November 19, 2020. https://papers.ssrn.com/abstract=3736255.

Chandrasekhar, Arun G., Esther Duflo, Michael Kremer, João F. Pugliese, Jonathan Robinson, and Frank Schilbach. "Blue Spoons: Sparking Communication About Appropriate Technology Use." Working Paper. Working Paper Series. National Bureau of Economic Research, September 2022. https://doi.org/10.3386/w30423.

Corral, Carolina, Xavier Giné, Aprajit Mahajan, and Enrique Seira. "Appropriate Technology Use and Autonomy: Evidence from Mexico." Cambridge, MA: National Bureau of Economic Research, August 2020. https://doi.org/10.3386/w27681.

Duflo, Esther, Daniel Keniston, Tavneet Suri, and Céline Zipfel. "Chat Over Coffee? Diffusion of Agronomic Practices and Market Spillovers in Ghana," 2023. https://www.nber.org/system/files/working_papers/w31368/w31368.pdf.

Emerick, Kyle, and Manzoor H. Dar. "Farmer Field Days and Demonstrator Selection for Increasing Technology Adoption." *The Review of Economics and Statistics* 103, no. 4 (September 28, 2021): 680–93. https://doi.org/10.1162/rest_a_00917.

Fafchamps, Marcel, Asad Islam, Abdul Malek, and Debayan Pakrashi. "Mobilizing P2P Diffusion for New Agricultural Practices: Experimental Evidence from Bangladesh." *The World Bank Economic Review* 35, no. 4 (November 1, 2021): 1076–1101. https://doi.org/10.1093/wber/lhab009.

Fishman, Ram, Jared Gars, Avinash Kishore, Patrick Ward, and Yoav Rothler. "Confidence and Information Usage: Evidence from Soil Testing in India," n.d.

Hanna, Rema, Sendhil Mullainathan, and Joshua Schwartzstein. "Learning Through Noticing: Theory and Evidence from a Field Experiment *." *The Quarterly Journal of Economics* 129, no. 3 (August 1, 2014): 1311–53. https://doi.org/10.1093/qje/qju015.

Harou, Aurélie P., Malgosia Madajewicz, Hope Michelson, Cheryl A. Palm, Nyambilila Amuri, Christopher Magomba, Johnson M. Semoka, Kevin Tschirhart, and Ray Weil. "The Joint Effects of Information

and Financing Constraints on Technology Adoption: Evidence from a Field Experiment in Rural Tanzania." *Journal of Development Economics* 155 (March 1, 2022): 102707. https://doi.org/10.1016/j.jdeveco.2021.102707.

Islam, Mahnaz, and Sabrin Beg. "Rule-of-Thumb Instructions to Improve Fertilizer Management: Experimental Evidence from Bangladesh." *Economic Development and Cultural Change* 70, no. 1 (October 2021): 237–81. https://doi.org/10.1086/711174.

Kondylis, Florence, and Valerie Mueller. "Seeing Is Believing? Evidence from a Demonstration Plot Experiment in Mozambique," November 12, 2013.

Pan, Yao, Stephen C Smith, and Munshi Sulaiman. "Agricultural Extension and Technology Adoption for Food Security: Evidence from Uganda." *American Journal of Agricultural Economics* 100, no. 4 (2018): 1012–31. https://doi.org/10.1093/ajae/aay012.

Takahashi, Kazushi, Yukichi Mano, and Keijiro Otsuka. "Learning from Experts and Peer Farmers about Rice Production Experimental Evidence from Cote dIvoire.Pdf." Google Docs, 2019. https://drive.google.com/file/d/1qtRvL868xBuFD-swt9JF_3IfHy3D18Vx/view?usp=embed_facebook.

Vasilaky, Kathryn N., and Kenneth L. Leonard. "As Good as the Networks They Keep? Improving Outcomes through Weak Ties in Rural Uganda." *Economic Development and Cultural Change* 66, no. 4 (July 2018): 755–92. https://doi.org/10.1086/697430.

8. Digital extension services

As discussed in the reviews on traditional extension and training and information delivery, a lack of timely, actionable information can be a key constraint to farmers' adoption of improved inputs and techniques. In many cases, it is not feasible for government extension agents to reach large numbers of farmers in person. Digital extension services delivered via mobile phones or other digital channels can close information gaps between farmers and extension providers by providing a low-cost option to administer timely, science-based advice directly to farmers or to augment the abilities of extension providers to provide high-quality advisory services. These services empower farmers to implement new farming techniques that increase yields, income, and food security and take action against climate shocks. There is **good evidence** for the effectiveness of digital extension to improve agricultural outcomes and adapt to climate change, but the link to food and nutrition security indicators is less clear.

Digital extension can significantly improve the adoption of agricultural inputs and yields, according to a meta-analysis from six countries (Fabregas et al., 2019). SMS-based extension is a popular low-cost means for digitally delivering extension advice, with evidence suggesting it can improve farmer practices. This is backed by evidence from Kenya and Rwanda (Fabregas et. al., 2022). Evidence from Ecuador confirmed that text messages can also increase the overall knowledge and adoption of complex agricultural technologies, such as integrated pest management to prevent environmental and health damages (Larochelle et al., 2017). Nonetheless, other delivery channels can also be effective. For example, voice-based extension increased the adoption of recommended seeds and complementary investments in India, and it also increased the adoption of recommended fertilizer types and amounts, although with no effects on yields (Cole and Fernando, 2021; Cole et al., 2023). Video-based extension improved agricultural practices and outcomes for farmers in India, Ethiopia, and Uganda (Baul et al., 2024; Abate et al., 2023; Van Campenhout et al., 2020). When combined with traditional extension, video screenings on integrated soil fertility management increased the adoption of recommended practices in Ethiopia, also affecting farmers who were non-actively involved in the training (Hörner et al., 2019). Mobile applications also show promise for increasing yields and profits and for optimizing input use (Arouna et al., 2020; Tjernström et al., 2021).

Adoption: Mobile phone penetration, especially smartphone penetration, is a key barrier to the adoption of digital extension. SMS-based extensions may be more widely accessible but are much more limited in the type of content that can be delivered. Interactive voice response (IVR) technologies show promise to deliver more detailed content among populations with lower levels of literacy and smartphone access (Cole and Fernando, 2021). Even so, farmers may fail to follow recommendations from digital services as a result of credit constraints, lack of trust, or other traditional constraints to technology adoption. The timing of messaging may also play a role in the effectiveness of digital services.

Cost-effectiveness: Highly cost-effective with relatively high fixed costs but low marginal costs of delivering information. Digital extension can reach significantly more people than in-person services at a low cost. Evidence from six trials in Kenya and Rwanda suggests benefit-cost ratios between 9:1 and 90:1, depending on scale. Studies in other contexts have faced issues of statistical power in estimating benefit-cost ratios. Still, a range of reasonable impacts on profits suggests IVR services in India would be highly cost-effective (Cole and Fernando, 2021). In each case, the cost-effectiveness is driven by more diffuse impacts on a larger

number of farmers. Digital agriculture can also be leveraged as a complement to traditional extension, sharing reminders with farmers, creating feedback for extension services, and increasing the flow of information more broadly.

Context: The effectiveness of digital extension services depends on the choice of delivery medium and the local context. Smartphone-based applications are unlikely to successfully reach a population of farmers with limited access to smartphones. SMS-based extensions might have muted impacts in contexts with increasing levels of SMS spam or where literacy levels are low. Although the technical costs of delivering voice or SMS content at scale should not vary sharply across contexts, in practice, the telecommunications environment might mean radically different implementation costs. The reach of traditional extension may facilitate the implementation of digital services through data about farmers' location and production practices.

Abate, Gashaw T., Tanguy Bernard, Simrin Makhija, and David J. Spielman. "Accelerating Technical Change through ICT- Evidence from a Video-Mediated Extension Experiment in Ethiopia." *World Development*, 2023. https://drive.google.com/file/d/18W4M6UG1qj5rnb0NQuxQwNHViD-K0uBf/view?usp=sharing&usp=embed_facebook.

Arouna, Aminou, Jeffrey D. Michler, Wilfried G. Yergo, and Kazuki Saito. "One Size Fits All? Experimental Evidence on the Digital Delivery of Personalized Extension Advice in Nigeria." *American Journal of Agricultural Economics* 103, no. 2 (2021): 596–619. https://doi.org/10.1111/ajae.12151.

Baul, Tushi, Dean Karlan, Kentaro Toyama, Kathryn N. Vasilaky, and Global Poverty Research Lab Submitter. "Improving Smallholder Agriculture via Video-Based Group Extension." SSRN Scholarly Paper. Rochester, NY, January 31, 2024. https://doi.org/10.2139/ssrn.4307353.

Cole, Shawn A, and A Nilesh Fernando. "'Mobile'Izing Agricultural Advice Technology Adoption Diffusion and Sustainability." *The Economic Journal* 131, no. 633 (January 1, 2021): 192–219. https://doi.org/10.1093/ej/ueaa084.

Cole, Shawn, Grady Killeen, Tomoko Harigaya, and Aparna Krishna. "Using Satellites and Phones to Evaluate and Promote Agricultural Technology Adoption: Evidence from Smallholder Farms in India," n.d.

Fabregas, Raissa, Michael Kremer, Matthew Lowes, Robert On, and Giulia Zane. "Digital Information Provision and Behavior Change: Lessons from Six Experiments in East Africa." Working Paper. Working Paper Series. National Bureau of Economic Research, January 2024. https://doi.org/10.3386/w32048.

Fabregas, Raissa, Michael Kremer, and Frank Schilbach. "Realizing the Potential of Digital Development: The Case of Agricultural Advice." Science 366, no. 6471 (December 13, 2019): eaay3038. https://doi.org/10.1126/science.aay3038.

Hörner, Denise, Adrien Bouguen, Markus Frölich, and Meike Wollni. "The Effects of Decentralized and Video-Based Extension on the Adoption of Integrated Soil Fertility Management - Experimental Evidence from Ethiopia." NBER, 2019. https://www.nber.org/system/files/working_papers/w26052/w26052.pdf.

Larochelle, Catherine, Jeffrey Alwang, Elli Travis, Victor Hugo Barrera, and Juan Manuel Dominguez Andrade. "Did You Really Get the Message? Using Text Reminders to Stimulate Adoption of Agricultural Technologies." *The Journal of Development Studies* 55, no. 4 (April 3, 2019): 548–64. https://doi.org/10.1080/00220388.2017.1393522.

Tjernström, Emilia, Travis J. Lybbert, Rachel Frattarola Hernández, and Juan Sebastian Correa. "Learning by (Virtually) Doing: Experimentation and Belief Updating in Smallholder Agriculture." *Journal of Economic Behavior & Organization* 189 (September 2021): 28–50. https://doi.org/10.1016/j.jebo.2021.03.001.

Van Campenhout, Bjorn, David J. Spielman, and Els Lecoutere. "Information and Communication Technologies to Provide Agricultural Advice to Smallholder Farmers: Experimental Evidence from Uganda." *American Journal of Agricultural Economics* 103, no. 1 (2021): 317–37. https://doi.org/10.1002/ajae.12089.

9. Weather forecasting

There are a range of public, private, and nonprofit organizations seeking to deliver improved weather forecasts to farmers in more effective and cost-effective ways. The objective of weather forecasts is to minimize yield loss resulting from unpredictable weather patterns. Short-term forecasts alert farmers to prepare for sudden shocks or provide up-to-date rainfall and heat information. Long-term forecasts facilitate better planning for crop selection in seasonal strategies. Both of these approaches contribute to improving yields and reducing losses caused by fluctuations in short and long-run weather. There is **high potential evidence** on the effects of weather forecasting to improve farmer yields, incomes, and climate resilience. However, this is based on a limited number of studies that do not include food and nutrition security outcomes.

Receiving appropriately-timed, higher-quality forecasts is likely to allow farmers to optimize input investments. Studies in India have explored the relationship between forecasts, behavior change, investment decisions, and profits. A study using household surveys and historical rainfall data shows that improvements in the accuracy of the onset of the monsoon from the 25th to the 75th percentile of the distribution would increase gross agricultural income by 8 to 9 percent (Giné et. al., 2015). Another study shows that even modest improvements in forecast quality could substantially increase average profits for farmers, and high returns to increasing forecast quality remain even under global warming conditions of high variability in rainfall (Rosenzweig and Udry, 2013). In a third study, the delivery of improved forecasts of the monsoon onset affects farmer behavior and agricultural outcomes, helping farmers to make better investment decisions in the face of variable weather (Burlig et al., 2024). In Benin, providing basic precipitation forecasts to farmers during the rainy season has shown the potential to improve labor productivity, reduce labor costs, and enhance yield (Yegbemey et al., 2023). Providing farmers in Ghana with accurate short-term forecasts can be a cheap and effective approach to inducing behavior change, but forecasts alone may not be enough to increase profits (Fosu et al., 2018). However, evidence from Colombia and India shows that bundling weather forecasts and alerts with market price information had no effect on crop loss or profit (Camacho and Conover, 2019; Fafchamps and Minten, 2012)

Adoption: There is substantial variation in meteorological capabilities across countries and limited evidence on the best methods for delivering forecasts to farmers (World Bank, 2019). Importantly, farmers are responsive to forecasts, and their responsiveness seems to increase with forecast skill (Rosenzweig and Udry, 2013). National meteorological services are typically underfunded and do not deliver information targeting farmers' needs. Importantly, institutional cooperation and novel forecasting techniques could help bridge these barriers. In West Africa, a set of regional and national meteorology services collaborate to generate seasonal forecasts, which now reach millions of farmers in Senegal and elsewhere in the region (Blundo-Canto et al., 2021; Burlig et al., 2024). More research is needed to determine how to best deliver improved forecasts to farmers across regions with different institutional and market conditions.

Cost-effectiveness: Unclear, likely highly cost-effective with relatively high fixed costs but low marginal costs of delivering information. There is limited evidence on the cost-effectiveness of improved weather forecasts, partly because weather forecasts are expensive and capturing the full set of benefits is challenging. There are two very different sets of costs to consider for improved forecasting. First, there is the cost of producing improved weather forecasts. If there are better "off the shelf" tools available for a forecasting agency, the cost might be limited to the human capital and technology infrastructure necessary to implement those tools. If agencies must instead invest in research to improve on existing models, this may require substantially more and riskier investments. A 2019 World Bank report provides an extremely detailed look at current practices and opportunities to improve investment at this level (World Bank, 2019).

The second issue to consider is delivering information to farmers more effectively. For this, there is a high potential to use the tools discussed in the digital extension review to deliver information in a low-cost way. Overall, weather forecasting interventions are likely cost-effective. This is because of the low marginal cost of delivering forecasts via radio, mobile phones, or SMS. However, more data-intensive infrastructure and tailoring to process and report forecasts may be required, which might increase costs. Nevertheless, more research is needed to understand the best ways to communicate complicated probabilistic information and to optimally localize farmers for accurate forecast targeting. However, a study in India found that farmers understand probabilistic information with little training (Cole et al., 2023)

Context: The existing landscape of weather forecasting may vary widely from one context to the next. National meteorological systems vary across regions and tend to be dramatically underfunded in low-income countries. Within countries, variations in forecast accuracy are also relevant. In India, for example, the current long-run monsoon forecast is accurate in Kerala but much less useful for farmers in other states since the monsoon does not proceed predictably from there. Improved long-run monsoon forecasts could substantially enhance agricultural outcomes in other regions (Burlig et al., 2024). Even when accurate forecasts are available, finding effective delivery mechanisms and communicating information that is useful to farmers has its challenges.

Blundo Canto, Genowefa, Nadine Andrieu, Nawalyath Soulé Adam, Ousmane Ndiaye, and Brian Chiputwa. "Scaling Weather and Climate Services for Agriculture in Senegal: Evaluating Systemic but Overlooked Effects." *Climate Services* 22 (April 1, 2021): 100216. https://doi.org/10.1016/j.cliser.2021.100216.

Burlig, Fiona, Amir Jina, Erin M Kelley, Gregory V Lane, and Harshil Sahai. "Long-Range Forecasts As Climate Adaptation: Experimental Evidence From Developing-Country Agriculture," 2024.

Camacho, Adriana, and Emily Conover. "The Impact of Receiving SMS Price and Weather Information on Small Scale Farmers in Colombia." *World Development*, 2019. https://drive.google.com/file/d/1u_z4Dy-M1l-8RAqy89SpVzHW0UyrGnamV/view?usp=sharing&usp=embed_facebook.

Cole, Shawn, Tomoko Harigaya, and Vaishnavi Surendra. "Weather Forecasts and Farmers' Beliefs after False Alarms," 2023.

Fafchamps, Marcel, and Bart Minten. "Impact of SMS-Based Agricultural Information on Indian Farmers." *The World Bank Economic Review*, 2012. https://drive.google.com/file/d/1FAF0TxZjcVhYF-IF4DRTMh2g-69JgTLG5/view?usp=sharing&usp=embed_facebook.

Gine, Xavier, Robert M Townsend, and James Vickery. "Forecasting When It Matters: Evidence from Semi-Arid India," n.d.

Ibrahim, Mohammed. "Disseminating Innovative Resources and Technologies to Smallholder Farmers in Ghana: Results of the Weather Forecasting Program." *IPA*, n.d.

Rosenzweig, Mark, and Christopher R. Udry. "Forecasting Profitability." Working Paper. Working Paper Series. National Bureau of Economic Research, August 2013. https://doi.org/10.3386/w19334.

World Bank. *Weathering the Change*. World Bank, Washington, DC, 2019. https://doi.org/10.1596/31507.

Yegbemey, Rosaine N., Gunther Bensch, and Colin Vance. "Weather Information and Agricultural Outcomes: Evidence from a Pilot Field Experiment in Benin." *World Development* 167, no. C (2023). https://econpapers.repec.org/article/eeewdevel/v_3a167_3ay_3a2023_3ai_3ac_3as0305750x22003680.htm.

10. Bundled interventions

There are different types of bundled services targeting smallholder farmers. One group of interventions is bundled extension services, which provide asset-based financing, agricultural training, and information services. Another group of interventions is more limited packages, such as genetic-financial bundles or credit for quality-improving technology (Boucher et al., 2022). By offering comprehensive packages of services, including asset-based financing, agricultural training, and information dissemination, these interventions tackle multiple barriers at once. Farmers gain access to various resources and support mechanisms, enhancing their productivity, financial stability, and access to essential resources. These bundles exploit complementarities between different components. There is **high potential evidence** on the effects of bundled interventions to improve smallholder agricultural productivity and climate resilience. However, this assessment is based on a limited number of studies that do not document effects on food and nutrition security or other related outcomes.

Bundling training and credit access may improve agricultural outcomes among a subset of farmers. In Kenya, a program that provided maize farmers with a bundle of group-liability loans for inputs, insurance, training, and market support was effective at raising yields, production, and profits (Deutschmann et al., 2023). Similar findings were observed in Ethiopia (Abate et al. 2018). These findings were consistent across different groups of participants. To enroll in the program, however, farmers had to meet some basic criteria for participating in the program. In Mozambique and Tanzania, an intervention that provided farmers with drought-tolerant seeds and insurance found that seeds fully protected farmers against mid-season yield losses from drought and, when paired with the index insurance, led to excess mitigation, by which adopters intensified investments in the year following the drought (Boucher et al., 2022). Insurance complemented seeds by mitigating the impact of severe yield shocks, which also led to excess mitigation. In Colombia, a bundle of different contractual arrangements with coffee farmers (training, extension services and access to inputs, and a commitment to purchase at a fixed price premium conditional on quality) represented an increase in farmers production in the regions being upgraded to high quality (Macchiavello and Miquel-Florensa, 2019).

Adoption: Multiple constraints limit smallholder productivity, including liquidity, risk, and information. Bundled interventions aim to address more than one of these constraints or address a single constraint in multiple ways. Social enterprises and non-profits offering bundled interventions to smallholder farmers have proliferated in the past fifteen years. However, these models still have a fairly limited scale, and most charge a fee for their services, potentially excluding some of the poorest small-scale producers. Nonetheless, the evidence indicates that learning effects can encourage adoption. For example, farmers who experience the benefits of bundling drought-tolerant seeds with index insurance continue to intensify investment in productive inputs, but farmers for whom the benefits are not salient may disadopt over time (Boucher et al., 2019).

There is a gap in the literature exploring ways to encourage the adoption of bundled interventions. For example, the demand for insurance products alone is highly price sensitive, but solely increasing payout is not always effective. An intervention in India found that farmers do not fully trust or understand insurance,

and their level of trust significantly affects demand (Cole et al., 2013). In this case, demand was 36 percent higher when the person offering rainfall insurance was previously endorsed by a trusted source. Bundled interventions could induce higher trust through training components or more personalized interactions, but this has not been tested empirically.

Cost-effectiveness: Unclear, like highly cost-effective, but more external evaluations are needed. Most evidence on the cost-effectiveness of these programs stems from program-managed monitoring and evaluation, rather than rigorous external evaluations. An exception is an evaluation in Kenya, which finds significant positive net benefits (Deutschmann et al., 2023). Some programs report a sizable social return on investment, ranging from $2.70 to $3.57 per dollar invested, but these estimates should be caveated appropriately (One Acre Fund, 2023; myAgro, 2021). Further research to isolate the effects of individual components could help simplify these bundles and lower costs across different contexts.

Context: Identifying which constraints are most salient for farmers in a given context matters for the effective design of bundled interventions. For example, risk might be a more binding constraint than credit in some settings, making a case for simplified bundles. In Ghana, an intervention that provided cash grants, free rainfall insurance, or paid rainfall insurance found that demand for insurance was strong, and insurance led to significantly larger agricultural investment and riskier production choices (Karlan et al., 2014). However, cash grants had a relatively small effect. This indicates that a main constraint to farmer investment was uninsured risk and that liquidity constraints were not as binding as expected: when provided with insurance, farmers were able to find resources to increase investments. Identifying the right constraints is essential to ensure the cost-effectiveness of interventions. Along those lines, bundling multiple ineffective or non-cost-effective programs is unlikely to achieve cost-effective outcomes, as evidence suggests may be the case for Millenium Village projects (Masset et al., 2020). Finally, bundling insurance and other services could be particularly relevant in settings affected by climate change, though additional research is needed (Aheeyer et al., 2021).

BIBLIOGRAPHY

Abate, Gashaw Tadesse, Tanguy Bernard, Alan de Brauw, and Nicholas Minot. "The Impact of the Use of New Technologies on Farmers' Wheat Yield in Ethiopia: Evidence from a Randomized Control Trial." *Agricultural Economics* 49, no. 4 (2018): 409–21. https://doi.org/10.1111/agec.12425.

Boucher, Stephen, Michael Carter, Jon Einar Flatnes, Travis Lybbert, Jonathan Malacarne, Paswel Marenya, and Laura Paul. "Bundling Genetic and Financial Technologies for More Resilient and Productive Small-Scale Agriculture." Cambridge, MA: National Bureau of Economic Research, September 2021. https://doi.org/10.3386/w29234.

Boucher, Stephen R, Michael R Carter, Jon Einar Flatnes, Travis J Lybbert, Jonathan G Malacarne, Paswel P Mareyna, and Laura A Paul. "Bundling Genetic and Financial Technologies for More Resilient and Productive Small-Scale Farmers in Africa." *The Economic Journal*, February 12, 2024, ueae012. https://doi.org/10.1093/ej/ueae012.

Cole, Shawn, Xavier Giné, Jeremy Tobacman, Petia Topalova, Robert Townsend, and James Vickery. "Barriers to Household Risk Management: Evidence from India." *American Economic Journal: Applied Economics* 5, no. 1 (January 1, 2013): 104–35. https://doi.org/10.1257/app.5.1.104.

Deutschmann, Joshua W., Maya Duru, Kim Siegal, and Emilia Tjernstrom. "Relaxing Multiple Agricultural Productivity Constraints at Scale." SSRN Scholarly Paper. Rochester, NY, June 15, 2023. https://doi.org/10.2139/ssrn.4479905.

Karlan, Dean, Robert Osei, Isaac Osei-Akoto, and Christopher Udry. "Agricultural Decisions after Relaxing Credit and Risk Constraints *." *The Quarterly Journal of Economics* 129, no. 2 (May 1, 2014): 597–652. https://doi.org/10.1093/qje/qju002.

Macchiavello, Rocco, and Josepa Miquel-Florensa. "Buyer-Driven Upgrading in GVCs: The Sustainable Quality Program in Colombia," n.d.

Masset, Edoardo, Jorge García-Hombrados, and Arnab Acharya. "Aiming High and Falling Low: The SADA-Northern Ghana Millennium Village Project." *Journal of Development Economics* 143 (March 1, 2020): 102427. https://doi.org/10.1016/j.jdeveco.2019.102427.

MyAgro. "myAgro Quarterly report." Accessed September 3, 2024. https://www.myagro.org/wp-content/uploads/2021/08/fy-21_q23-report_myagro.pdf.

One Acre Fund. "The Life You Can Save" One Acre Fund, 2021.https://www.thelifeyoucansave.org/best-charities/one-acre-fund/.

11. Livestock management practices

Livestock management programs encompass a wide range of practices, including training on animal husbandry, establishing grazing rights, and changes to livestock rearing, housing, and feeding. Livestock management programs provide information about and incentives for vaccines, health, and feed management practices. By improving livestock health, farmers achieve higher yields from their livestock and increase their income. Healthy livestock can also help insure farmers against climate shocks. Overall, there is **high potential evidence** on outcomes related to productivity and income and mixed evidence on food and nutrition security. However, these types of practices can vary significantly with context. This review focuses on management practices more relevant to small-scale farms or grazing systems rather than intensive production.

Livestock interventions can improve productivity and incomes. In Nepal, a program with animal husbandry training components nearly doubled incomes (Miller et al., 2014). A combination of training in management strategies, livestock husbandry practices, and fodder production in Tajikistan resulted in higher net incomes that persisted despite drought shocks (Cavatassi and Mallia, 2019). These effects on economic outcomes and resilience were accompanied by training in techniques that reduce the environmental impact of husbandry, like rotational grazing. In Uganda, reforms in the dairy sector to encourage milk production, along with the introduction of improved dairy breeds, may have improved milk yields and food security– though this is not based on experimental evidence (Kabunga, 2014). In Myanmar and Uganda, training farmers on poultry-rearing practices, including administering vaccinations and providing supplementary feed for poultry, also boosted productivity (Henning et al., 2009; Bessell et al., 2020).

However, there is mixed evidence on the effects of livestock management on nutrition outcomes. Evidence from Nepal indicates positive effects on children's height, weight, and health-related practices but no impacts on health scores or school attendance among families who receive training in a community development program (Miller et al., 2014). Data from Tajikistan also shows positive effects on some anthropometric measures like children's height but no impact on weight or body mass index (BMI) (Cavatassi and Mallia, 2019). There is also evidence indicating that the intervention increased food insecurity and reduced diet diversity.

Adoption: The adoption of livestock management practices is limited by supply and demand-side constraints. Livestock R&D is slower and more costly than crop research (Nin et al., 2007). In Sub-Saharan Africa, inadequate investments in livestock R&D have limited the development of locally appropriate improved feed and breeds (Erdaw, 2023)). At the same time, there is limited rigorous evidence assessing mechanisms to boost demand and adoption. A scoping review suggests several strategies, though these are largely untested in experimental settings (Lindahl et al., 2020). These include, targeting women to participate in training programs; having champions for each intervention; using participatory approaches; implementing farmer-led interventions; bundling different interventions; and microfinance. Videos, village meetings, and pamphlet handouts seem to be effective interventions to improve knowledge dissemination based on limited evidence from Ethiopia and Tanzania (Stringer et al., 2018; Bell et al., 2005). In Uganda,

a “contact farmer” extension model improves technology adoption, production practices, and revenue (Behaghel et al., 2020).

Context: The appropriateness of livestock management practices varies across settings. For example, practices that prevent the spread of disease in congregate settings are not as relevant in extensive grazing systems. Livestock production is also one of the few feasible agricultural activities in some harsh environments. The effects of climate change, combined with increasing demand for animal products, may accelerate the transition to intensive production systems, which would call for a new set of practices. Climate adaptation strategies may include effectively storing feed and using silage, collecting and storing water, managing diet quality, implementing rotational grazing, using better-adapted livestock breeds, and implementing biosecurity measures to monitor the spread of diseases, based on two systematic reviews (1, 2) (Herrero et al., 2015; Godde et al., 2021). Climate change may also drive conflict between agriculturalists and pastoralist groups (McGuirk and Nunn, 2020).

Cost-effectiveness: Unclear, likely high with some evidence showing that management can be more cost-effective than veterinary vaccines. Cost-effectiveness will depend on how much information needs to be tailored and the costs of delivering information. There is limited evidence on the cost-effectiveness of improved livestock management programs. Evidence from Myanmar shows that vaccinations have a higher benefit-cost ratio than poultry management practices- 28.8 compared to 4.7 (Henning et al., 2013).

Behagel, Luc, Jérémie Gignoux, and Karen Macours. "Social Learning in Agriculture: Does Smallholder Heterogeneity Impede Technology Diffusion in Sub-Saharan Africa?" CEPR, 2020. https://www.parisschoolofeconomics.eu/docs/macours-karen/cepr-dp15220.pdf.

Bell, C. E., N. P. French, E. Karimuribo, N. H. Ogden, M. J. Bryant, E. M. Swai, D. M. Kambarage, and J. L. Fitzpatrick. "The Effects of Different Knowledge-Dissemination Interventions on the Mastitis Knowledge of Tanzanian Smallholder Dairy Farmers." *Preventive Veterinary Medicine* 72, no. 3 (December 12, 2005): 237–51. https://doi.org/10.1016/j.prevetmed.2005.05.004.

Bessell, Peter, Roy Woolley, Stuart Stevenson, Lamyaa Al-Riyami, Patrick Opondo, Leslie Lai, and Neil Gammon. "An Analysis of the Impact of Newcastle Disease Vaccination and Husbandry Practice on Smallholder Chicken Productivity in Uganda.Pdf." *Preventative Veterinary Medicine*, 2020. https://drive.google.com/file/d/1Y2WjrcUDThofVDJeoG-Vmbmk5K-XwYbY/view?usp=sharing&usp=embed_facebook.

Cavatassi, Romina, and Paola Mallia. "IFAD Impact Assessment – Livestock and Pasture Development Project (LPDP): Tajikistan." SSRN Scholarly Paper. Rochester, NY, May 16, 2019. https://doi.org/10.2139/ssrn.3389336.

———. "Impact Assessment Report." IFAD, 2018. https://www.ifad.org/documents/38714170/41114919/TJ_LPDP_IA+report.pdf.

Erdaw, M. M. (2023). Contribution, prospects and trends of livestock production in sub-Saharan Africa: a review. International Journal of Agricultural Sustainability, 21(1). https://doi.org/10.1080/14735903.2023.2247776

Godde, C.M., D. Mason-D'Croz, D.E. Mayberry, P.K. Thornton, and M. Herrero. "Impacts of Climate Change on the Livestock Food Supply Chain; a Review of the Evidence." *Global Food Security* 28 (March 2021): 100488. https://doi.org/10.1016/j.gfs.2020.100488.

Henning, J., J. Morton, R. Pym, T. Hla, and J. Meers. "Evaluation of Strategies to Improve Village Chicken Production-Controlled Field Trials to Assess Effects of Newcastle Disease Vaccination and Altered Chick Rearing in Myanmar." *Preventive Veterinary Medicine* 90, no. 1 (July 1, 2009): 17–30. https://doi.org/10.1016/j.prevetmed.2009.04.007.

Henning, J., J. Morton, R. Pym, T. Hla, K. Sunn, and J. Meers. "Economic analysis of interventions to improve village chicken production in Myanmar." Preventive veterinary medicine 110, no. 3-4 (2013): 525-540.

Herrero, Mario, Stefan Wirsenius, Benjamin Henderson, Cyrille Rigolot, Philip Thornton, Petr Havlík, I.J.M. Boer, and Pierre J. Gerber. "Livestock and the Environment: What Have We Learned in the Past Decade?" *Annual Review of Environment and Resources* 40 (November 4, 2015): 177–202. https://doi.org/10.1146/annurev-environ-031113-093503.

Kabunga, Nassul. "Improved Dairy Cows in Uganda: Pathways to Poverty Alleviation and Improved Child Nutrition," n.d.

Lindahl, Johanna F., Florence Mutua, and Delia Grace. "Evaluating Farm-Level Livestock Interventions in Low-Income Countries: A Scoping Review of What Works, How, and Why." *Animal Health Research Reviews* 21, no. 2 (December 2020): 108–21. https://doi.org/10.1017/S1466252320000146.

McGuirk, Eoin F., and Nathan Nunn. "Transhumant Pastoralism, Climate Change, and Conflict in Africa." Working Paper. Working Paper Series. National Bureau of Economic Research, December 2020. https://doi.org/10.3386/w28243.

Miller, Laurie C., Neena Joshi, Mahendra Lohani, Beatrice Rogers, Meghan Loraditch, Robert Houser, Padma Singh, and Shubh Mahato. "Community Development and Livestock Promotion in Rural Nepal: Effects on Child Growth and Health." *Food and Nutrition Bulletin* 35, no. 3 (September 2014): 312–26. https://doi.org/10.1177/156482651403500304.

Nin Pratt, Alejandro, Simeon Ehui, and Samuel Benin. "Chapter 47 Livestock Productivity in Developing Countries: An Assessment." *Handbook of Agricultural Economics* 3 (December 31, 2007): 2461–2532. https://doi.org/10.1016/S1574-0072(06)03047-7.

Stringer, Andrew P., Rob M. Christley, Catriona E. Bell, Feseha Gebreab, Gebre Tefera, Karen Reed, Andrew Trawford, and Gina L. Pinchbeck. "Evaluating the Efficacy of Knowledge-Transfer Interventions on Animal Health Knowledge of Rural Working Equid Owners in Central Ethiopia: A Cluster-Randomized Controlled Trial." *Frontiers in Veterinary Science* 5 (November 20, 2018). https://doi.org/10.3389/fvets.2018.00282.

12. Veterinary services

Veterinary interventions provide a range of services to livestock owners, including vaccination against diseases such as Newcastle disease (ND), East Coast fever (ECF), Foot and Mouth disease (FMD), Peste des petits ruminants (PPR), and Brucellosis. These programs aim to reduce livestock illness and deaths, thus increasing the overall productivity of the flock/herd and household incomes. By vaccinating livestock intended for consumption, the risk of human contamination is reduced. Better livestock health and survival also enhance food security for farmers. Overall, there is **high potential evidence** regarding the efficacy of veterinary service programs on productivity and food and nutrition security, as well as emerging evidence on their cost-effectiveness. There is limited direct evidence on climate resilience, but no papers included climate outcomes.

There is good evidence that vaccination programs improve productivity in poultry operations, yet the literature is less definitive on whether this translates into higher incomes. Vaccination against ND, for example, has been shown to reduce poultry deaths by more than half in Myanmar and increase flock size and productivity in Tanzania and by nearly 60 percent in Uganda (Henning et al., 2009; Knueppel et al., 2010; Bessell et al., 2020). In Myanmar, Nepal, India, and Tanzania, poultry productivity improvements made via vaccines translated into higher sales and incomes (Henning et al., 2009; Bessell et al., 2017). However, studies in Tanzania and Kenya found no significant impact on incomes and sales, respectively (Knueppel et al., 2010; Otiang et al., 2021).

There is also good evidence that vaccination programs targeting assets managed by women - such as poultry - can have positive effects on children's nutrition and health. In Myanmar, Tanzania, Nepal, India, and Kenya, ND vaccinations increased animal protein consumption, particularly among children (Henning et al., 2009; Bessell et al., 2017; Otiang et al., 2021). In Tanzania, vaccination programs improved food security among participating households, while in Kenya, ND vaccination led to significant improvements in anthropometric measures among both boys and girls under the age of 5 (Knueppel et al., 2010; Otiang et al., 2022).

Similar effects have been reported for cattle vaccination programs, but the evidence is scarcer and less conclusive. ECF is a leading cause of calf mortality in eastern and southern Africa. In Tanzania, vaccinating cattle against ECF significantly decreased cattle mortality and increased profits (Martins et al., 2010). Non-experimental evidence from four regions in Kenya where ECF vaccinations were provided for free to 16 percent of cattle found modest but positive effects on food expenditures, education expenditures, and school attendance (Marsh et al., 2016).

Adoption: The availability of effective livestock vaccines and drugs is often limited by market and institutional failures. There is limited R&D for many tropical animal diseases that are endemic to Sub-Saharan Africa (SSA), which is further constrained by viral diversity. FMD, for example, has multiple strains that are highly location-specific and have been linked to $2.3 billion in annual losses in SSA alone (Knight-Jones and Rushton, 2013). Without a vaccine matched to the circulating serotype, vaccination is an

extraneous expense without any assured benefits (Railey and Marsh, 2019). Even when appropriate services may be available, adoption is often low. Deficient last-mile infrastructure, supply chain challenges, and lack of awareness of the risks and expected cost of disease drive the relative cost of vaccination, particularly for less profitable animals like small ruminants (Wane et al., 2020). Pre-existing beliefs about healthcare and lack of trust in veterinary services also play a role (Heffernan et al., 2010; Wane et al., 2020).

There is some evidence that information diffusion strategies can improve adoption, but this is still a fairly limited area of research. In Mali, providing information leaflets resulted in knowledge and management improvements - though there was evidence that learning decays five months after the intervention (Grace et al., 2008). Village meetings, pamphlet handouts, and videos have also been effective in increasing farmer knowledge in Tanzania and Ethiopia (Bell et al., 2005; Stringer et al., 2008). A non-experimental study in Tanzania, Nepal, and India found that training local individuals as independent vaccinators was highly effective at inducing uptake (Bessell et al., 2017). Digital tools and complementary interventions could help address some of the adoption barriers previously discussed.

Cost-Effectiveness: Highly cost-effective, particularly providing vaccines. There is evidence that vaccination programs can be cost-effective, but it largely stems from non-experimental studies. Studies in Kenya and Tanzania found that the benefits of ECF vaccinations would significantly outweigh the costs (Marsh et al., 2016; Martins et al., 2010). In Mongolia, a model of introducing a 10-year mass vaccination campaign against Brucellosis found the program to be highly cost-effective: a 52 percent reduction of transmission would cost US$8.3 million and result in benefits of USD$26.6 million, a cost-benefit ratio of 3.2 (Roth et al., 2003).

Context: The effectiveness of vaccination programs holds in different contexts. However, there is limited evidence on the heterogeneity of these effects by herd, flock, or farm size. Non-experimental evidence from Tanzania suggests that households with larger chicken flocks are more likely to participate in vaccination programs (de Bruyn et al., 2017). Poultry farmers in areas where previous vaccination programs took place were more likely to participate in vaccination programs and were more knowledgeable (Lindahl et al., 2019). This may suggest a possible snowball effect, where vaccination programs increase flock size and improve farmer knowledge, thus encouraging continued vaccination.

Bell, C. E., N. P. French, E. Karimuribo, N. H. Ogden, M. J. Bryant, E. M. Swai, D. M. Kambarage, and J. L. Fitzpatrick. "The Effects of Different Knowledge-Dissemination Interventions on the Mastitis Knowledge of Tanzanian Smallholder Dairy Farmers." *Preventive Veterinary Medicine* 72, no. 3–4 (December 12, 2005): 237–51. https://doi.org/10.1016/j.prevetmed.2005.05.004.

Bessell, Paul, Peetambar Kushwaha, Roggers Mosha, Roy Woolley, Lamyaa Al-Riyami, and Neil Gammon. "Assessing the Impact of a Novel Strategy for Delivering Animal Health Interventions to Smallholder Farmers." *Preventive Veterinary Medicine* 147 (August 1, 2017). https://doi.org/10.1016/j.prevetmed.2017.08.022.

Bessell, Peter, Roy Woolley, Stuart Stevenson, Lamyaa Al-Riyami, Patrick Opondo, Leslie Lai, and Neil Gammon. "An Analysis of the Impact of Newcastle Disease Vaccination and Husbandry Practice on Smallholder Chicken Productivity in Uganda.Pdf." *Preventative Veterinary Medicine*, 2020. https://drive.google.com/file/d/1Y2WjrcUDThofVDJeoG-Vmbmk5K-XwYbY/view?usp=embed_facebook.

Bruyn, Julia de, Peter C. Thomson, Brigitte Bagnol, Wende Maulaga, Elpidius Rukambile, and Robyn G. Alders. "The Chicken or the Egg? Exploring Bi-Directional Associations between Newcastle Disease Vaccination and Village Chicken Flock Size in Rural Tanzania." *PloS One* 12, no. 11 (2017): e0188230. https://doi.org/10.1371/journal.pone.0188230.

Grace, Delia, Thomas Randolph, Oumar Diall, and Peter-Henning Clausen. "Training Farmers in Rational Drug-Use Improves Their Management of Cattle Trypanosomosis: A Cluster-Randomised Trial in South Mali." *Preventive Veterinary Medicine* 83, no. 1 (January 1, 2008): 83–97. https://doi.org/10.1016/j.prevetmed.2007.06.005.

Heffernan, Claire, Kim Thomson, and Louise Nielsen. "Caste, Livelihoods and Livestock: An Exploration of the Uptake of Livestock Vaccination Adoption among Poor Farmers in India." *Journal of International Development* 23, no. 1 (2011): 103–18. https://doi.org/10.1002/jid.1643.

Henning, J., J. Morton, R. Pym, T. Hla, and J. Meers. "Evaluation of Strategies to Improve Village Chicken Production-Controlled Field Trials to Assess Effects of Newcastle Disease Vaccination and Altered Chick Rearing in Myanmar." *Preventive Veterinary Medicine* 90, no. 1 (July 1, 2009): 17–30. https://doi.org/10.1016/j.prevetmed.2009.04.007.

Knight-Jones, T.J.D., and J. Rushton. "The Economic Impacts of Foot and Mouth Disease – What Are They, How Big Are They and Where Do They Occur?" *Preventive Veterinary Medicine* 112, no. 3–4 (November 1, 2013): 161–73. https://doi.org/10.1016/j.prevetmed.2013.07.013.

Knueppel, Danielle, Carol Cardona, Peter Msoffe, Montague Demment, and Lucia Kaiser. "Impact of Vaccination against Chicken Newcastle Disease on Food Intake and Food Security in Rural Households in Tanzania." *Food and Nutrition Bulletin* 31, no. 3 (September 2010): 436–45. https://doi.org/10.1177/156482651003100306.

Lindahl, Johanna F., Jarrah Young, Amanda Wyatt, Mary Young, Robyn Alders, Brigitte Bagnol, Augustino Kibaya, and Delia Grace. "Do Vaccination Interventions Have Effects? A Study on How Poultry Vaccination Interventions Change Smallholder Farmer Knowledge, Attitudes, and Practice in Villages in Kenya and Tanzania." *Tropical Animal Health and Production* 51, no. 1 (January 2019): 213–20. https://doi.org/10.1007/s11250-018-1679-3.

Marsh, Thomas L., Jonathan Yoder, Tesfaye Deboch, Terry F. McElwain, and Guy H. Palmer. "Livestock Vaccinations Translate into Increased Human Capital and School Attendance by Girls." *Science Advances* 2, no. 12 (December 14, 2016): e1601410. https://doi.org/10.1126/sciadv.1601410.

Martins, S. Babo, G. Di Giulio, G. Lynen, A. Peters, and J. Rushton. "Assessing the Impact of East Coast Fever Immunisation by the Infection and Treatment Method in Tanzanian Pastoralist Systems." *Preventive Veterinary Medicine* 97, no. 3–4 (December 1, 2010): 175–82. https://doi.org/10.1016/j.prevetmed.2010.09.018.

Otiang, Elkanah, Samuel M. Thumbi, Zoë A. Campbell, Lucy W. Njagi, Philip N. Nyaga, and Guy H. Palmer. "Impact of Routine Newcastle Disease Vaccination on Chicken Flock Size in Smallholder Farms in Western Kenya." *PloS One* 16, no. 3 (2021): e0248596. https://doi.org/10.1371/journal.pone.0248596.

———. "Impact of Routine Newcastle Disease Vaccination on Chicken Flock Size in Smallholder Farms in Western Kenya." *PLOS ONE* 16, no. 3 (March 18, 2021): e0248596. https://doi.org/10.1371/journal.pone.0248596.

Otiang, Elkanah, Jonathan Yoder, Shanthi Manian, Zoë A. Campbell, Samuel M. Thumbi, Lucy W. Njagi, Philip N. Nyaga, and Guy H. Palmer. "Vaccination of Household Chickens Results in a Shift in Young Children's Diet and Improves Child Growth in Rural Kenya." *Proceedings of the National Academy of Sciences* 119, no. 24 (June 14, 2022): e2122389119. https://doi.org/10.1073/pnas.2122389119.

Railey, Ashley F., and Thomas L. Marsh. "A Rational Explanation of Limited FMD Vaccine Uptake in Endemic Regions." *Pathogens* 8, no. 4 (December 2019): 181. https://doi.org/10.3390/pathogens8040181.

Roth, Felix, Jakob Zinsstag, Dontor Orkhon, G. Chimed-Ochir, Guy Hutton, Ottorino Cosivi, Guy Carrin, and Joachim Otte. "Human health benefits from livestock vaccination for brucellosis: case study." Bulletin of the World health Organization 81 (2003): 867-876.

Stringer, Andrew P., Rob M. Christley, Catriona E. Bell, Feseha Gebreab, Gebre Tefera, Karen Reed, Andrew Trawford, and Gina L. Pinchbeck. "Evaluating the Efficacy of Knowledge-Transfer Interventions on Animal Health Knowledge of Rural Working Equid Owners in Central Ethiopia: A Cluster-Randomized Controlled Trial." *Frontiers in Veterinary Science* 5 (November 20, 2018). https://doi.org/10.3389/fvets.2018.00282.

Wane, Abdrahmane, Michel Dione, Barbara Wieland, Karl M. Rich, Awa Sadio Yena, and Abdou Fall. "Willingness to Vaccinate (WTV) and Willingness to Pay (WTP) for Vaccination Against Peste Des Petits Ruminants (PPR) in Mali." *Frontiers in Veterinary Science* 6 (January 15, 2020). https://doi.org/10.3389/fvets.2019.00488.

13. Climate-smart agriculture

Climate-smart agriculture (CSA) is an approach that enables and encourages actors within farming systems to adapt to climate change (FAO, 2024). Climate-smart practices aim to encourage sustainable intensification and natural resource management while mitigating climate impacts. These include a range of practices like sustainable agricultural practices (SAPs), conservation agriculture (CA), sustainable land management (SLM), and multiple agricultural technologies (MATs). Practices may include crop rotation, using climate-resilient seeds, cover crops, composting, tillage, crop diversification, fertilizer management, integrated pest management, and land preparation to conserve water and reduce run-off. By adopting these strategies, farmers can protect their yields from changing weather patterns, ultimately enhancing agricultural sustainability and livelihoods. Climate-smart practices vary significantly, which represents a challenge for assessing their effectiveness as a broad intervention category. There is also limited experimental work. Within the available literature, there is good evidence that CSA improves resilience during climate shocks, **high potential evidence** for improving productivity and incomes, and a lack of evidence on food and nutrition security. One challenge for this research is that many climate-smart practices aim to improve resilience when facing climate shocks, which may not happen during the period covered by the research. As a result, much of the research focuses on the adoption of CSA practices.

There is inconclusive evidence on the effects of climate-smart practices on productivity and incomes. A meta-analysis of 48 crops in 63 countries shows that, on average, no-till agriculture lowers yields unless it is combined with other practices like crop rotation and residue retention (Pittelkow et al., 2014). In Zimbabwe, however, conservation agriculture increased maize yields during rainfall shocks but had negligible or slightly negative effects on yields during normal years (Michler et al., 2019). Experimental evidence from Niger also shows that rainwater harvesting with techniques that can combat land degradation and improve soil fertility can increase yields by almost 40 percent in the short term (Aker and Jack, 2021).

There is no rigorous experimental evidence assessing the effects of climate-smart agriculture on food security. In Malawi, farmers who participated in a training program and adopted at least one climate-smart practice - including agroforestry, apiculture, check dams, continuous contour trenches, stone bunds, marker ridges, vetiver grass, and water absorption trenches - reported higher yields four years after the intervention, which was also linked to positive effects on food security (Amadu et al., 2020).

Adoption: Non-experimental evidence indicates that the adoption of climate-smart practices is low and may be linked to access to complementary services (Stevenson and Vlek, 2018). Some factors associated with their adoption are perceptions of soil quality and access to hired labor and extension services (Amadu et al., 2020), and barriers may include risk, short-term declines in yields and profits, and increasing labor needs (Stevenson and Vlek, 2018). Over the long term, some CA practices like no-till may offer potential benefits. However, the short-term negative effects may preclude most farmers from adopting them, as summarized in this scoping review (Brouder and Gomez-Macpherson, 2014). Lack of information also limits adoption, but leveraging social learning can be effective, based on experimental evidence from Malawi (1; 2) (BenYishay and Mobarak, 2019; Beaman et al., 2021).

Cost-effectiveness: Unclear, likely mixed to account for tailoring information content and delivery to new contexts. No information about delivery formats. There is no reliable evidence on the cost-effectiveness of climate-smart practices. A scoping review of CA concluded that the literature lacks adequately described information on crop performance and management of residues, which may play a role in the dearth of reliable cost-effectiveness and impact data (Brouder and Gomez-Macpherson, 2014). Climate-smart practices need to be tailored to local contexts, and it may take a while to iterate in each place to determine which practices are effective.

Context: The effectiveness and appropriateness of climate-smart practices vary with agronomic conditions, farm size, value chain, and other contextual factors (Stevenson et al., 2019). For example, non-experimental evidence from Ethiopia shows that, among other factors, the adoption of SLM practices is higher among farmers with pump irrigation systems compared to farmers who rely on gravity irrigation, and farmers may adopt these practices in the face of extreme weather events as a risk management strategy (Bekele et al., 2021). The benefits of SLM practices like minimum tillage also depend on the agricultural potential of the local soil, being more effective than commercial fertilizer in low-potential agricultural areas (Kassie et al., 2010). However, there is no rigorous evidence assessing heterogeneous effects. Evidence from Ethiopia also highlights context variability in technology adoption (Kosmowski et al., 2020).

Aker, Jenny C, and B Kelsey Jack. "Harvesting the Rain: The Adoption of Environmental Technologies in the Sahel." *Nber*, 2021. https://www.nber.org/system/files/working_papers/w29518/w29518.pdf.

Amadu, Festus O., Paul E. McNamara, and Daniel C. Miller. "Yield Effects of Climate-Smart Agriculture Aid Investment in Southern Malawi." *Food Policy* 92, no. C (2020). https://ideas.repec.org//a/eee/jfpoli/v92y2020ics0306919220300713.html.

Beaman, Lori, Ariel BenYishay, Jeremy Magruder, and Ahmed Mushfiq Mobarak. "Can Network Theory-Based Targeting Increase Technology Adoption?" *American Economic Review* 111, no. 6 (June 2021): 1918–43. https://doi.org/10.1257/aer.20200295.

Bekele, Rahel Deribe, Alisher Mirzabaev, and Dawit Mekonnen. "Adoption of Multiple Sustainable Land Management Practices among Irrigator Rural Farm Households of Ethiopia." *Land Degradation & Development* 32, no. 17 (2021): 5052–68. https://doi.org/10.1002/ldr.4091.

BenYishay, Ariel, and A Mushfiq Mobarak. "Social Learning and Incentives for Experimentation and Communication." *The Review of Economic Studies* 86, no. 3 (May 1, 2019): 976–1009. https://doi.org/10.1093/restud/rdy039.

Brouder, Sylvie, and Helena Gomez-Macpherson. "The Impact of Conservation Agriculture on Smallholder Agricultural Yields: A Scoping Review of the Evidence." *Agriculture, Ecosystems & Environment* 187 (April 1, 2014). https://doi.org/10.1016/j.agee.2013.08.010.

Fao. "Overview | Climate-Smart Agriculture | Food and Agriculture Organization of the United Nations." Accessed June 11, 2024. https://www.fao.org/climate-smart-agriculture/overview/en/.

Kassie, Menale, Precious Zikhali, John Pender, and Gunnar Köhlin. "The Economics of Sustainable Land Management Practices in the Ethiopian Highlands." *Journal of Agricultural Economics* 61, no. 3 (2010): 605–27. https://doi.org/10.1111/j.1477-9552.2010.00263.x.

Kosmowski, Frederic, Solomon Alemu, Paola Mallia, James Stevenson, and Karen Macours. "Shining a Brighter Light: Comprehensive Evidence on Adoption." *CGIAR*, n.d.

Michler, Jeffrey, Kathy Baylis, Mary Arends-Kuenning, and Kizito Mazvimavi. "Conservation Agriculture and Climate Resilience." *Journal of Environmental Economics and Management* 93 (December 1, 2018). https://doi.org/10.1016/j.jeem.2018.11.008.

Pittelkow, Cameron M., Xinqiang Liang, Bruce A. Linquist, Kees Jan van Groenigen, Juhwan Lee, Mark E. Lundy, Natasja van Gestel, Johan Six, Rodney T. Venterea, and Chris van Kessel. "Productivity Limits and Potentials of the Principles of Conservation Agriculture." *Nature* 517, no. 7534 (January 2015): 365–68. https://doi.org/10.1038/nature13809.

Stevenson, J, and P Vlek. "Assessing the Adoption and Diffusion of Natural Resource Management Practices: Synthesis of a New Set of Empirical Studies | IAES | CGIAR Independent Advisory and Evaluation Services." *CGIAR*, December 13, 2018. https://iaes.cgiar.org/spia/publications/assessing-adoption-and-diffusion-natural-resource-management-practices-synthesis.

Stevenson, James, Bernard Vanlauwe, Karen Macours, Nancy Johnson, Lakshmi Krishnan, Frank Place, David Spielman, Karl Hughes, and Paul Vlek. "Farmer Adoption of Plot- and Farm-Level Natural Resource Management Practices: Between Rhetoric and Reality." *Global Food Security* 20 (March 1, 2019): 101–4. https://doi.org/10.1016/j.gfs.2019.01.003.

14. Integrated pest management

Integrated pest management (IPM) promotes methods to reduce or replace the application of synthetic pesticides. IPM can be used as a preventive measure through proper crop rotation or resistant varieties, as a monitoring method by regularly scouting plants for pests and diseases, or as an eradication mechanism using biopesticides and biocontrol agents. Integrated pest management reduces agricultural losses caused by invasive pests by providing farmers with a range of pest control strategies. IPM can also improve farm profitability by reducing excess expenditure on pesticides. However, some IPM practices require more labor, which may offset savings on pesticides. There is **low evidence** that IPM practices can improve income and reduce environmental degradation, but there is no evidence on outcomes related to food and nutrition security. IPM typically requires tailored farmer training and access to complementary services and inputs, which affects its suitability across different contexts and target groups.

There is limited rigorous evidence linking IPM to higher yields or incomes for farmers. Non-experimental evidence from Pakistan indicates that farmer field schools (FFSs) can incentivize the adoption of IPM, leading to higher yields (Ali and Sharif, 2012). Similar effects were observed in Bangladesh, though these varied by crop type (Gautam et al., 2017). Non-experimental studies in Kenya and Bangladesh found that IPM can improve profits by reducing production costs from pesticide use and crop losses (Kibira et al., 2015; Rahman and Norton, 2019). IPM training might improve the handling of pesticides, which can be harmful to farmers (Gautam et al., 2017). Nonetheless, there is limited causal evidence to back these findings.

Adoption: The adoption of IPM typically requires targeted training and complementary inputs. To an extent, farmer field schools have been found to be an effective way to increase pest knowledge and induce IPM adoption (Ali and Sharif, 2012). In Pakistan, FFSs seem to have enhanced knowledge of the adoption of pest scouting, the application of fewer doses of pesticides, and a better understanding of beneficial and harmful pests (Ali and Sharif, 2012). In Bangladesh and Uganda, targeted training increased awareness of pests and helped optimize pesticide use (Gautam et al., 2017; Lerva, 2022). However, the evidence remains limited.

Cost-effectiveness: Unclear, likely mixed to account for tailoring information content and delivery to new contexts. No information about delivery formats. There is no reliable evidence on the cost-effectiveness of IPM. A review of Conservation Agriculture (CA) found inadequate information on crop performance and residue management, contributing to the lack of reliable data on cost-effectiveness and consistency. Most studies examine a broad range of IPM practices and do not disaggregate by practice. Isolating the impact of specific components could be an initial step in determining the cost-effectiveness of IPM. FFSs, which have been used to promote IPM, can reduce farmers' environmental impact as a result of reduced pesticide use. However, they have also been found to be excessively expensive when implemented at a large scale (Waddington et al., 2014).

Context: There are only a handful of studies assessing the effectiveness of IPM, most of which take place in South Asia. IPM covers a range of practices and may be constrained in several settings by knowledge gaps, the need for localized training, and limited access to pesticide alternatives.

BIBLIOGRAPHY

Ali, Akhter, and Muhammad Sharif. "Impact of Farmer Field Schools on Adoption of Integrated Pest Management Practices among Cotton Farmers in Pakistan." *Journal of the Asia Pacific Economy* 17, no. 3 (August 1, 2012): 498–513. https://doi.org/10.1080/13547860.2012.694706.

Gautam, Shriniwas, Pepijn Schreinemachers, Md. Nasir Uddin, and Ramasamy Srinivasan. "Impact of Training Vegetable Farmers in Bangladesh in Integrated Pest Management (IPM)." *Crop Protection* 102 (December 1, 2017): 161–69. https://doi.org/10.1016/j.cropro.2017.08.022.

Kibira, M., H. Affognon, B. Njehia, B. Muriithi, S. Mohamed, and S. Ekesi, eds. "Economic Evaluation of Integrated Management of Fruit Fly in Mango Production in Embu County, Kenya." *African Journal of Agricultural and Resource Economics*, 2015. https://doi.org/10.22004/ag.econ.229815.

Lerva, Benedetta. "The Monetary Value of Externalities: Experimental Evidence from Ugandan Farmers." Policy Research Working Papers. The World Bank, July 24, 2023. https://doi.org/10.1596/1813-9450-10521.

Rahman, Md. Sadique, and George W. Norton. "Farm-Level Impacts of Eggplant Integrated Pest Management: A Stochastic Frontier Production Function Approach." *International Journal of Vegetable Science* 25, no. 6 (November 2, 2019): 590–600. https://doi.org/10.1080/19315260.2019.1566188.

Waddington, Hugh, Birte Snilstveit, Jorge Hombrados, Martina Vojtkova, Daniel Phillips, Philip Davies, and Howard White. "Farmer Field Schools for Improving Farming Practices and Farmer Outcomes: A Systematic Review." *Campbell Systematic Reviews* 10, no. 1 (2014): i–335. https://doi.org/10.4073/CSR.2014.6.

15. On-farm mechanization

On-farm mechanization aims to boost productivity and optimize labor and other inputs. Interventions to increase mechanization take several forms, including equipment rental, distributing farm implements, and mechanization as a service. Mechanization potentially plays a key role in agricultural transformation, increasing productivity and freeing up labor to work in other sectors. While programs to encourage mechanization are common, there is **low evidence** of the impacts of on-farm mechanization on productivity and food and nutrition security because only one study met our inclusion criteria.

One high-quality study measured the impact of increasing access to rental farm equipment among smallholder rice, cotton, and maize producers in Karnataka, India. Vouchers covering a third of mechanization costs increased the take-up of mechanization, increased productivity, and reduced labor use on farms (Caunedo and Kala, 2022). Take up of mechanization also led to higher revenues for off-farm businesses.

Adoption: The cost and availability of equipment may be barriers to take up of mechanization. Small farm sizes make owning equipment inefficient for many farmers. In the study in Karnataka, farmers were equally likely to take up mechanization regardless of prior experience with the equipment.

Cost-Effectiveness: Unclear, likely mixed based on whether farm equipment is cost effective for smallholder farmers. Equipment sharing schemes may be more cost effective.

Context: Geography and crop type heavily influence which equipment is feasible in a given area. However, where there is existing access to equipment, vouchers may improve access without specifying a particular type of mechanization.

BIBLIOGRAPHY

Caunedo, Julieta, and Namrata Kala. "Mechanizing Agriculture." *NBER*, 2022.

Post-Harvest Interventions

1. Improved food storage

The primary storage method covered in the literature is triple-layered hermetic storage bags. Improved storage practices aim to prevent food losses from pests, water, spoilage, and weather variations. When used properly, these bags can prevent post-harvest losses and reduce the spread of foodborne toxins like aflatoxins. There is **good evidence** for the potential of improved storage to impact food security, nutrition, and agricultural productivity (primarily via reduced post-harvest losses). There is limited direct evidence on climate resilience, but in theory, storage bags can help households endure negative weather shocks by making stored food last longer and less susceptible to weather damage. The cost-effectiveness of these interventions may vary with the context and the design of the intervention.

Improved storage effectively reduced post-harvest losses in India, Kenya, Tanzania (1; 2), and Uganda, but several studies provided storage bags for free and were not able to test whether farmers were willing to purchase at market prices (Shukla et al., 2023; Ngedwa et al., 2016; Brander et al., 2021; Chegere et al., 2022; Omotilewa et al., 2018). Improved storage also reduces the risk of contamination with aflatoxins, based on evidence in Senegal (Bauchet et al., 2021). Households in Burkina Faso, India, and Tanzania who used improved storage faced substantial reductions in food insecurity, but not in experiments conducted in Kenya and Indonesia (Le Cotty et al., 2023; Shukla et al., 2023; Basu and Wong, 2015; Brander et al., 2021; Aggarwal et al., 2018). Farmers in Burkina Faso, Indonesia, and Kenya who used improved storage earned more income by selling crops later (Delavallade and Godlonton, 2023; Aggarwal et al., 2018; Basu and Wong, 2015). A study in Tanzania found that a hermetic bag intervention on its own did not improve food storage or revenue, but that increased access to credit did (Channa et al., 2022). A study in Sierra Leone found that neither inventory credit nor traditional storage support improved storage behavior or sales patterns (Casaburi et al., 2014).

Adoption: Evidence from Uganda suggests subsidies for improved storage can crowd in additional purchases by farming households, but evidence from India finds the opposite: free distribution lowers future adoption Omotilewa et al., 2019; Shukla et al., 2022). An experiment in Kenya suggests that demand for hermetic storage is highly elastic, and an experiment in Niger found that the average willingness to pay for storage bags was 50 percent of the market price (Channa et al., 2019; Aker et al., 2023).

Cost-effectiveness: Mixed. Individual storage bags are likely more cost-effective than public storage warehouses, but WTP tends to be lower than market prices. Evidence from Indonesia suggests that an organized storage or warehouse credit intervention, with procurement costs spread over a two-year period, yielded relatively modest to high benefit-cost ratios, ranging from 43% to 75% for storage and 46% to 80% for credit. However, these benefit-cost ratios do not fully account for implementation costs (Basu and Wong 2015). Combining improved storage with training in Tanzania had a positive net benefit for farmers and, accounting for training costs, may achieve positive net social benefits in about three years (Chegere et al., 2022). In India, evidence suggests farmers recover the full cost of investing in improved storage in one

season. A warehouse storage program in Burkina Faso resulted in production value gains about nine times higher than program costs, but program costs do not account for the cost of constructing new warehousing facilities (Delavallade and Godlonton, 2023).

Context: The extent to which farmers sell crops and can profit from higher prices later in the season or reduced postharvest losses is likely a key determinant of success in interventions promoting improved storage. It is important to consider general equilibrium effects as interventions scale: widespread availability of improved storage is likely to dampen the price arbitrage gains for individual farmers.

Aggarwal, S., B. Giera, D. Jeong, J. Robinson, and A. Spearot. "Market Access, Trade Costs, and Technology Adoption: Evidence from Northern Tanzania." Monograph. NBER, 2018. http://dx.doi.org/10.3386/w25253.

Aker, Jenny C., Brian Dillon, and C. Jamilah Welch. "Demand, Supply and Long-Term Adoption: Evidence from a Storage Technology in West Africa." *Journal of Development Economics* 165, no. C (2023). https://econpapers.repec.org/article/eeedeveco/v_3a165_3ay_3a2023_3ai_3ac_3as0304387823000846.htm.

Basu, Karna, and Maisy Wong. "Evaluating Seasonal Food Storage and Credit Programs in East Indonesia." *Journal of Development Economics* 115 (July 2015): 200–216. https://doi.org/10.1016/j.jdeveco.2015.02.001.

Bauchet, Jonathan, Stacy Prieto, and Jacob Ricker-Gilbert. "Improved Drying and Storage Practices That Reduce Aflatoxins in Stored Maize: Experimental Evidence from Smallholders in Senegal." *American Journal of Agricultural Economics* 103, no. 1 (2021): 296–316. https://doi.org/10.1111/ajae.12106.

Brander, Michael, Thomas Bernauer, and Matthias Huss. "Improved On-Farm Storage Reduces Seasonal Food Insecurity of Smallholder Farmer Households – Evidence from a Randomized Control Trial in Tanzania." *Food Policy* 98 (January 2021): 101891. https://doi.org/10.1016/j.foodpol.2020.101891.

Channa, Hira, Jacob Ricker-Gilbert, Shiferaw Feleke, and Tahirou Abdoulaye. "Overcoming Smallholder Farmers' Post-Harvest Constraints through Harvest Loans and Storage Technology: Insights from a Randomized Controlled Trial in Tanzania." *Journal of Development Economics* 157, no. C (2022). https://ideas.repec.org//a/eee/deveco/v157y2022ics030438782200027x.html.

Chegere, Martin Julius, Håkan Eggert, and Måns Söderbom. "The Effects of Storage Technology and Training on Postharvest Losses, Practices, and Sales: Evidence from Small-Scale Farms in Tanzania." *Economic Development and Cultural Change* 70, no. 2 (January 2022): 729–61. https://doi.org/10.1086/713932.

Delavallade, Clara, and Susan Godlonton. "Locking Crops to Unlock Investment: Experimental Evidence on Warrantage in Burkina Faso." *Journal of Development Economics* 160, no. C (2023). https://ideas.repec.org//a/eee/deveco/v160y2023ics0304387822001031.html.

Harvard University, Lorenzo Casaburi, Rachel Glennerster, Massachusetts Institute of Technology, Tavneet Suri, Massachusetts Institute of Technology, Sullay Kamara, and Center for Economic and Social Policy Research. "Providing Collateral and Improving Product Market Access for Smallholder Farmers: A Randomized Evaluation of Inventory Credit in Sierra Leone." 2015th ed. International Initiative for Impact Evaluation, February 2015. https://doi.org/10.23846/ow31180.

Le Cotty, Tristan, Elodie Maitre d'Hotel, and Julie Subervie. "Inventory Credit to Enhance Food Security in Burkina Faso." *SIDALC*, n.d.

Ndegwa, Michael K., Hugo De Groote, Zachary M. Gitonga, and Anani Y. Bruce. "Effectiveness and Economics of Hermetic Bags for Maize Storage: Results of a Randomized Controlled Trial in Kenya." *Crop Protection* 90 (December 1, 2016): 17–26. https://doi.org/10.1016/j.cropro.2016.08.007.

Omotilewa, O. J. "Does Improved Storage Technology Promote Modern Input Use and Food Security? Evidence from a Randomized Trial in Uganda." *SIDALC*, November 2018.

Omotilewa, Oluwatoba J., Jacob Ricker-Gilbert, and John Herbert Ainembabazi. "Subsidies for Agricultural Technology Adoption: Evidence from a Randomized Experiment with Improved Grain Storage Bags in Uganda." *American Journal of Agricultural Economics* 101, no. 3 (2019): 753–72. https://doi.org/10.1093/ajae/aay108.

Shukla, Varsha, and Rahul Arora. "The Economic Cost of Rising Non-Communicable Diseases in India: A Systematic Literature Review of Methods and Estimates." *Applied Health Economics and Health Policy* 21, no. 5 (September 1, 2023): 719–30. https://doi.org/10.1007/s40258-023-00822-8.

2. Agriculture supply chains

Interventions aimed at improving agriculture supply chains intend to improve access to input or output markets. Missing or incomplete supply chains may limit access to or the affordability of inputs, and a lack of access to output markets may mean farmers do not profit from productivity enhancements. Supply chain interventions take a variety of approaches, including, quality upgrading, increasing traceability and quality control along the supply chain, increasing farmer confidence in input quality, and providing price information to farmers, among others. By improving how supply chains function, these interventions aim to improve access to quality inputs and better output prices to improve agricultural productivity. Overall, there is **mixed evidence** on the impacts of supply chain interventions on agricultural productivity and income, with some encouraging evidence on quality upgrading and evidence of limited impacts of providing price information. There is a lack of evidence on nutrition and climate resilience, which are not often target outcomes for this category of interventions.

Quality upgrading. Interventions that encourage quality upgrading often provide incentives for producing higher-quality crops to attain higher prices in output markets. A review of the experimental literature finds that farmers respond to interventions that encourage quality upgrading. However, benefits from creating small-scale quality grading systems rarely exceed the certification costs borne by farmers, and no studies look at impacts at scale (J-PAL, 2021). In Senegal, onion farmers selling in markets where onions were labeled by weight and quality practices adopted quality upgrading processes, leading to higher incomes (Bernard et al., 2017). In India, incentive payments and information for lower microbial milk lead to improvements in milk quality and increased production (Rao and Shenoy, 2023).

One common approach to encourage or reward quality upgrading is through certification systems that pay premiums to farmers who agree to a set of standards that aim to achieve sustainable agricultural production. According to a review of descriptive and non-causal studies, these systems are linked with an increase in farmgate prices and income for certified farmers (Oya et al. 2018). Some quasi-experimental studies showed that quality and sustainability standards, like Fairtrade, Organic, GlobalGap, and UTZ, increase sales prices and revenues in Costa Rica, calorie and micronutrient consumption in Uganda through higher incomes and gender equity, and quantities sold in Madagascar (Dragusanu et al., 2022; Chiputwa and Qaim, 2015; Subervie and Vagneron, 2013). However, an analysis of coffee growers in Central America warns that combining floor prices with no control of excess quantities sold using fairtrade certifications can undermine these benefits, benefitting certifiers instead of producers (de Janvry et al., 2015).

Output price information: Providing price information to farmers may change farmer behavior, but the evidence is mixed on impacts on incomes. In West Bengal, providing price information to potato farmers did not change average sales or prices (Mitra et al., 2018). In Maharashtra, price information through SMS had no impact on prices of tomatoes, onions, wheat, or soya, but kiosks providing wholesale soy price information in Madhya Pradesh increased soya prices by 1-3 percent (Fafchamps and Minten, 2012; Goyal, 2010). Providing market information through text and audio-based messages in Guinea-Bissau, including ranges of farmgate prices, increased cashew producers' selling prices by 2 percent in a year with high world

prices for this commodity (Álvarez Pereira et al. 2023). In Ghana, text messages with price information increased farmers' selling prices by 9 percent for yam (Soldani et al., 2023). In Colombia, price information did not impact farmers' ability to get a higher price (Camacho and Conover, 2019).

Cost-effectiveness: Cost-effectiveness for quality upgrading programs is mixed. Quality-upgrading incentives may be hard to sustain without continued investment. Though farmers respond to price incentives for quality, prices may still not outweigh the costs to improve output quality (J-PAL, 2021). Reducing costs for upgrading quality for farmers could increase the cost-effectiveness of the interventions. The cost-effectiveness of output price dissemination would depend on the scale of farmers that would benefit from price information and the speed of price transmission.

Context: Simply providing price information to farmers is unlikely to have significant effects on farmer incomes or price levels. Information alone does not give farmers strong bargaining power in the presence of high transport costs. Yet by providing price information to intermediaries or producers with direct access to markets, market prices converge, and producers may benefit–for example, among grain producers in Niger or fishers in Kerala (Aker, 2010; Jensen, 2007). For quality upgrading, building a reputation for selling high-quality goods over time may be particularly important in disorganized markets with multiple intermediaries and buyers (J-PAL, 2021).

Aker, Jenny C. "Information from Markets Near and Far: Mobile Phones and Agricultural Markets in Niger." *American Economic Journal: Applied Economics* 2, no. 3 (July 2010): 46–59. https://doi.org/10.1257/app.2.3.46.

Álvarez Pereira, Brais, Giulio Schinaia, Sebastian Schäber, Dayvikson Raiss Laval Tavares, and Adewusi Mendoça. "Impact of Market Information on Cashew Producers in Guinea-Bissau." PEP Working Paper Series, 2022. https://portal.pep-net.org/document/download/37041.

Bernard, Tanguy, Alain de Janvry, Samba Mbaye, and Elisabeth Sadoulet. "Expected Product Market Reforms and Technology Adoption by Senegalese Onion Producers." *American Journal of Agricultural Economics* 99, no. 4 (2017): 1096–1115. https://doi.org/10.1093/ajae/aax033.

Camacho, Adriana, and Emily Conover. "The Impact of Receiving SMS Price and Weather Information on Small Scale Farmers in Colombia." *World Development* 123, no. C (2019). https://econpapers.repec.org/article/eeewdevel/v_3a123_3ay_3a2019_3ai_3ac_3a12.htm.

Chiputwa, Brian, and Matin Qaim. "Sustainability Standards, Gender, and Nutrition among Smallholder Farmers in Uganda." *The Journal of Development Studies* 52, no. 9 (September 1, 2016): 1241–57. https://doi.org/10.1080/00220388.2016.1156090.

Dragusanu, Raluca, Eduardo Montero, and Nathan Nunn. "The Effects of Fair Trade Certification: Evidence from Coffee Producers in Costa Rica." *Journal of the European Economic Association* 20, no. 4 (August 1, 2022): 1743–90. https://doi.org/10.1093/jeea/jvac026.

Fafchamps, Marcel, and Bart Minten. "Impact of SMS-Based Agricultural Information on Indian Farmers." *The World Bank Economic Review* 26, no. 3 (January 1, 2012): 383–414. https://doi.org/10.1093/wber/lhr056.

Goyal, Aparajita. 2010. "Information, Direct Access to Farmers, and Rural Market Performance in Central India." American Economic Journal: Applied Economics, 2 (3): 22–45.

Janvry, Alain de, Craig McIntosh, and Elisabeth Sadoulet. "Fair Trade and Free Entry: Can a Disequilibrium Market Serve as a Development Tool?" *The Review of Economics and Statistic*s 97, no. 3 (July 1, 2015): 567–73. https://doi.org/10.1162/REST_a_00512.

Jensen, Robert. "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector." *The Quarterly Journal of Economics 122*, no. 3 (2007): 879–924. https://www.jstor.org/stable/25098864.

JPAL. "Incentivizing Higher-Quality Agricultural Outputs." The Abdul Latif Jameel Poverty Action Lab (J-PAL), September 15, 2021. https://www.povertyactionlab.org/policy-insight/incentivizing-higher-quality-agricultural-outputs.

Mitra, Sandip, Dilip Mookherjee, Maximo Torero, and Sujata Visaria. "Asymmetric Information and Middleman Margins: An Experiment with Indian Potato Farmers." *The Review of Economics and Statistics* 100, no. 1 (March 1, 2018): 1–13. https://doi.org/10.1162/REST_a_00699.

Oya, Carlos, Florian Schaefer, and Dafni Skalidou. "The Effectiveness of Agricultural Certification in Developing Countries: A Systematic Review." *World Development* 112 (December 2018): 282–312. https://doi.org/10.1016/j.worlddev.2018.08.001.

Rao, Manaswini, and Ashish Shenoy. "Got (Clean) Milk? Organization, Incentives, and Management in Indian Dairy Cooperatives," n.d.

Subervie, Julie, and Isabelle Vagneron. "A Drop of Water in the Indian Ocean? The Impact of GlobalGap Certification on Lychee Farmers in Madagascar." *World Development* 50 (2013): 57–73. https://doi.org/10.1016/j.worlddev.2013.05.002.

3. Aggregation and output market access models

Aggregation and output market access models include contract farming arrangements, farmer associations, and digital trading platforms to link buyers and farmers directly. They intend to benefit farmers by improving access to output markets, increasing price stability, and providing complementary services such as training, credit, insurance, and inputs, ultimately improving income and food security. While many studies look at the causal impacts of interventions delivered within a contract farming arrangement – such as credit, insurance, or information – few measure the impacts of the contract farming arrangement directly (Giné et al., 2012; Casaburi and Willis, 2018; Casaburi et al., 2014). There is **high potential evidence** suggesting contract farming and other aggregation and output market access strategies have the potential to improve farmers' incomes and food and nutrition security. There is some evidence that aggregation and output market access models can have an effect on food security and incomes, though more research is needed.

Contract Farming: Contract farming encourages vertical coordination by some combination of guaranteeing a fixed price for outputs and a reliable stream of inputs for wholesalers, input provision and credit for farmers, and production management guarantees. In Madagascar, participation in a contract farming arrangement decreased the duration of the hungry season by eight days on average, with the greatest benefits accruing to households with children (Bellemare and Novak, 2016). In Kenya, an NGO that linked farmers to export markets increased incomes for farmers growing export crops for the first time but collapsed after one year due to changes in import regulations (Ashraf et al., 2009). While several studies demonstrate positive impacts of interventions delivered in the context of contract farming arrangements–for example, credit monitoring in Malawi, SMS extension services in Kenya, or seasonal loans in Zambia–evidence on the contract farming model itself is scarce, but encouraging (Giné et al., 2012; Casaburi et al., 2014; Fink et al., 2020). In Benin, a randomized trial found that offering fixed-price contracts to rice farmers increased yields, share of output sold in the market, and per capita income (Arouna et al., 2021).

Digital Platforms: Another approach is digital trading platforms to connect farmers and buyers. In Uganda, a digital trading platform that connected individual maize farmers with traders led to a decrease in price dispersion across markets and increased revenues for larger farmers (Falcao Bergquist and McIntosh, 2021).

Adoption: From the farmer's perspective, contract farming offers farmers a guaranteed offtake market for their produce before planting, making input and planting decisions less risky. It may also provide access to complementary services such as credit or input provision. For the buyer, contract farming can aggregate produce from a large number of small farms in quantities that are appropriate for larger-scale sales. Nonetheless, there is limited research assessing how to best incentivize the adoption of these models in practice.

Cost-effectiveness: Unclear, likely mixed based on the type of intervention (contract farming, digital output markets). None of the included studies address the cost-effectiveness of contract farming models.

The digital platform in Uganda had a dispersed impact across a large number of participants and a very low cost per farmer, suggesting it was strongly cost-beneficial.

Context: The appropriateness and impact of contract farming arrangements will heavily depend on the particular value chain and crop, in particular, whether multiple buyers make side-selling likely. For trading platforms and contract arrangements, trust between the contractor and farmer is important. Farm size may also play a role in the effectiveness of these models. In Uganda, the digital platform allowed farmers to connect with higher levels of the market, but impacts were concentrated among the largest-scale farmers (Falcao Bergquist and McIntosh, 2021).

Arouna, Aminou, Jeffrey Michler, and Jourdain Lokossou. "Contract Farming and Rural Transformation: Evidence from a Field Experiment in Benin." *SSRN Electronic Journa*l, January 1, 2018. https://doi.org/10.2139/ssrn.3277696.

Ashraf, Nava, Xavier Giné, and Dean Karlan. "Finding Missing Markets (and a Disturbing Epilogue): Evidence from an Export Crop Adoption and Marketing Intervention in Kenya," n.d.

Bellemare, Marc F., and Lindsey Novak. "Contract Farming and Food Security." *American Journal of Agricultural Economics* 99, no. 2 (2017): 357–78. https://doi.org/10.1093/ajae/aaw053.

Casaburi, Lorenzo, Michael Kremer, Sendhil Mullainathan, and Ravindra Ramrattan. "Harnessing ICT to Increase Agricultural Production: Evidence from Kenya," 2013. https://arefiles.ucdavis.edu/uploads/filer_public/2014/03/27/casaburi_et_al_ict_agriculture_20140306.pdf.

Casaburi, Lorenzo, and Jack Willis. "Time versus State in Insurance: Experimental Evidence from Contract Farming in Kenya." *The American Economic Review* 108, no. 12 (2018): 3778–3813. https://www.jstor.org/stable/26562918.

Falcao Bergquist, Lauren, and Craig McIntosh. "Search Cost, Intermediation, and Trade: Experimental Evidence from Ugandan Agricultural Markets," August 13, 2021. https://doi.org/10.26085/C3759K.

Fink, Günther, B. Kelsey Jack, and Felix Masiye. "Seasonal Liquidity, Rural Labor Markets, and Agricultural Production." *American Economic Review* 110, no. 11 (November 1, 2020): 3351–92. https://doi.org/10.1257/aer.20180607.

Giné, Xavier, Jessica Goldberg, and Dean Yang. "Credit Market Consequences of Improved Personal Identification: Field Experimental Evidence from Malawi." *American Economic Review* 102, no. 6 (October 1, 2012): 2923–54. https://doi.org/10.1257/aer.102.6.2923.

Availability & affordability interventions

This section categorizes interventions focused on making food more accessible and affordable to farmers and rural households.

1. Cash and in-kind transfers

Cash and in-kind transfers are social protection interventions that provide cash or assets directly to households. Transfers may be unconditional or conditional on recipients completing pre-specified actions, such as school attendance, bringing children to the doctor, or growth monitoring, and often are combined with social marketing campaigns around health and nutritional diversity. In-kind and cash transfer initiatives aim to enhance the resilience of rural ultra-poor households to external shocks. Transfers help offset costs, enabling recipients to reallocate income towards food, household items, assets, or savings. Adaptive cash transfers are described in another section ("Adaptive Social Protection") and can be offered ahead of climate events to help households prepare and take preventative actions. These programs are widespread, with 77 percent and 42 percent (WB, 2017) of countries globally implementing some form of unconditional and conditional cash transfer programs, respectively, and 60 percent (WB, 2017) of countries implementing some form of in-kind transfer program. There is **great evidence** on the effectiveness of cash and in-kind transfers for food and nutrition security and climate resilience, while the evidence on agricultural outcomes is promising but more limited. However, cash transfers are often meant to address multiple outcomes at once, and focusing on one outcome alone may be inappropriate. Relative cost-effectiveness varies by context, and cost-effectiveness is not widely documented, but cash transfers tend to be more cost-effective than in-kind transfers. Note that this review does not focus on graduation programs, which are covered in the next section.

Cash transfer programs can significantly improve food security and health. In Honduras, Kenya (1,2,3), Mexico (1,2,3), Liberia, Malawi, Nicaragua, Nigeria, Rwanda, and Zambia, conditional and unconditional cash transfers improved consumption, food expenditures, food security, nutritional status, the calorie density or quality of food consumed, and several health outcomes, especially for children (Benedetti et al., 2016; Almås et al., 2023; Egger et al., 2022; Banerjee et al., 2020; Aggarwal et al., 2023; Aggarwal et al., 2023; Macours et al., 2012; Carneiro et al., 2021; McIntosh and Zeitlin, 2021; AIR, 2016). In Mexico, an unconditional cash transfer to the elderly in rural areas increased protein and carbohydrate intake but did not see a significant change in body mass index. However, studies in Ecuador and Tanzania find no clear pattern of changes in diet or food expenditures among cash transfer recipients (Paxson and Schady, 2010; Evans et al., 2014). A meta-analysis evaluating the impact of cash transfer programs on child development found a significant reduction in stunting and an improvement in dietary diversity in children under five years but no effect on wasting (Manley et al., 2020). In the Philippines, cash transfer beneficiary children experienced reduced incidence of severe stunting and improvements in diet quality, with effects concentrated among the most disadvantaged (Filmer et al., 2018). In-kind food transfers show more mixed evidence. Randomized comparisons of cash, in-kind, and voucher transfers in Niger, Yemen, Rwanda, and Ecuador suggest that the relative effects of each type of intervention on caloric intake and dietary diversity depend heavily on the context (Hoddinott et al., 2018; Schwab, 2019; McIntosh and Zeitlin, 2021; Hidrobo et al., 2014).

There is relatively less evidence on the effects of transfer programs on agricultural outcomes of interest. In the longer run, cash transfer programs can increase productive and agricultural asset ownership, as well as agricultural income, based on evidence from Liberia, Malawi, Mexico, Tanzania, and Zambia. Cash transfers may also improve agricultural outcomes by relaxing credit constraints, which are binding for smallholder farmers in many contexts (Aggarwal et al., 2023; Aggarwal et al., 2023; Gertler et al., 2012; Evans et al., 2014; AIR, 2016). The increase in agricultural and non-agricultural assets, income source diversification, improvements in credit positions, and better housing conditions may be associated with a better position to cope with weather and economic shocks (AIR, 2016). The cash transfer itself is the most important coping mechanism for beneficiaries in the program in Zambia (AIR, 2016).

Adoption: Ineffective targeting of conditional or means-tested transfer programs may constrain adoption or impacts. This review discusses some strategies for the effective delivery of cash transfers (MacLeod et al., 2021). There is some evidence from Honduras that ineffective conditions reduce the impacts of conditional transfers specifically (Benedetti et al., 2016). The structure of cash transfers (timing and lumpiness) can impact their effects on household income and consumption (Kansikas et al., 2023). In Niger, evidence suggests that using mobile money to distribute cash transfers after an intense drought and harvest failures can improve dietary diversity and calorie consumption due to time savings and changes in intrahousehold bargaining power (Aker et al., 2016). Additionally, evidence from Malawi suggests that providing transfers in cash or via direct deposit to bank accounts does not substantially impact the composition of household spending (Brune et al., 2017).

In some cases, cash transfers may only be impactful when combined with information delivery. In Myanmar, a maternal cash transfer program significantly reduced stunting when combined with a social behavior change communication campaign, but not when cash was given alone (Field and Maffioli, 2021). Similarly, in Bangladesh, cash transfers improved children's height for age z-scores, but only when combined with behavior change communication (Ahmed et al., 2019). In Nepal, delivering information regarding nutrition and child care for children below the age of two improved maternal health and knowledge both with and without a cash transfer. However, knowledge gains were much larger with information combined with cash, and only in the combined group did child development improve (Levere et al., 2019).

Cost-effectiveness: Highly cost-effective. Cash transfers are usually more cost-effective compared to in-kind transfers. The evidence suggests in-kind food transfers are much less cost-effective than cash or voucher transfers for improving food security outcomes. For example, in Ecuador, Yemen, Uganda, and Niger, the cost to provide a food transfer is 2-3.8 times as expensive as providing a cash transfer or voucher (Hidrobo et al., 2014; Schwab, 2019; Margolies and Hoddinott, 2014; Hoddinott et al., 2018). A review of costs of different cash and in-kind transfers found that the per-transfer cost of providing cash is always less than food when activity-based costing methods are applied to interventions situated in Ecuador, Niger, Uganda, and Yemen. Given the budget for these interventions, an additional 44,769 people could have received assistance at no additional cost had cash been provided instead of food (Margolies and Hoddinott, 2014). Whether a cash transfer or voucher is relatively more cost-effective depends on the objective of a given program (for example, whether caloric intake or dietary diversity is the most important outcome). In Niger, providing cash transfers by mobile money was more costly to set up initially due to the provision of mobile phones to beneficiaries, but was 20 percent cheaper to administer otherwise (Aker et al., 2016). However, the cost-effectiveness of cash transfers is generally not well documented.

Context: The general equilibrium effects of cash transfers may vary across contexts. In India, for example, the effects of cash transfers on children's nutritional status were conditional on sanitation status; the program only had positive effects on nutritional status in places with better sanitation environments (Weaver et al., 2024). In Kenya, for example, unconditional cash transfers had positive spillover benefits,

with nearby non-recipient households increasing consumption despite small effects on local prices (Egger et al., 2022). By contrast, in the Philippines, conditional cash transfers increased relative to local prices of protein-rich perishable foods, causing non-recipient households to substitute away from nutritious and protein-rich foods (Filmer et al., 2018). Randomized comparisons of cash, in-kind, and voucher transfers in Niger, Yemen, Rwanda, and Ecuador suggest that the relative effects of each type of intervention on caloric intake and dietary diversity depend heavily on the context (Hoddinott et al., 2018; Schwab, 2018; McIntosh and Zeitlin, 2021; Hidrobo et al., 2014).

Aggarwal, Shilpa, Jenny C Aker, Dahyeon Jeong, Naresh Kumar, David Sungho Park, Jonathan Robinson, and Alan Spearot. "The Dynamic Effects of Cash Transfers: Evidence from Rural Liberia and Malawi," n.d.

Aggarwal, Shilpa, Jenny C Aker, Dahyeon Jeong, Naresh Kumar, David Sungho Park, and Alan Spearot. "The Dynamic Effects of Cash Transfers: Evidence from Liberia and Malawi." VoxDev, 2023. https://voxdev.org/topic/public-economics/dynamic-effects-cash-transfers-evidence-liberia-and-malawi.

Ahmed, Akhter, John F. Hoddinott, and Shalini Roy. "Food Transfers, Cash Transfers, Behavior Change Communication and Child Nutrition: Evidence from Bangladesh." 0 ed. Washington, DC: International Food Policy Research Institute, 2019. https://doi.org/10.2499/p15738coll2.133420.

AIR. "Zambia's Child Grant Program: 48-Month Impact Report." AIR, 2016. https://transfer.cpc.unc.edu/wp-content/uploads/2021/04/Zambia-CGP-48-Mo-Report.pdf.

Aker, Jenny C., Rachid Boumnijel, Amanda McClelland, and Niall Tierney. "Payment Mechanisms and Antipoverty Programs: Evidence from a Mobile Money Cash Transfer Experiment in Niger." *Economic Development and Cultural Change* 65, no. 1 (October 2016): 1–37. https://doi.org/10.1086/687578.

Almås, Ingvild, Johannes Haushofer, and Anders Kjelsrud. "The Income Elasticity for Nutrition: Evidence from Unconditional Cash Transfers in Kenya." Cambridge, MA: National Bureau of Economic Research, March 2019. https://doi.org/10.3386/w25711.

Banerjee, Abhijit, Michael Faye, Alan Krueger, Paul Niehaus, and Tavneet Suri. "Effects of a Universal Basic Income during the Pandemic," n.d.

Behrman, Jere R., and John Hoddinott. "Programme Evaluation with Unobserved Heterogeneity and Selective Implementation: The Mexican PROGRESA Impact on Child Nutrition." *Oxford Bulletin of Economics and Statistics* 67, no. 4 (2005): 547–69. https://doi.org/10.1111/j.1468-0084.2005.00131.x.

Benedetti, Fiorella, Pablo Ibarrarán, and Patrick J. McEwan. "Do Education and Health Conditions Matter in a Large Cash Transfer? Evidence from a Honduran Experiment." *Economic Development and Cultural Change* 64, no. 4 (July 2016): 759–93. https://doi.org/10.1086/686583.

Brune, Lasse, Xavier Gine, Jessica Goldberg, and Dean Yang. "Savings Defaults and Payment Delays for Cash Transfers: Field Experimental Evidence from Malawi," n.d.

Carneiro, Pedro, Lucy Kraftman, Giacomo Mason, Lucie Moore, Imran Rasul, and Molly Scott. "The Impacts of a Multifaceted Prenatal Intervention on Human Capital Accumulation in Early Life." *American Economic Review* 111, no. 8 (August 2021): 2506–49. https://doi.org/10.1257/aer.20191726.

Egger, Dennis, Johannes Haushofer, Edward Miguel, Paul Niehaus, and Michael Walker. "General Equilibrium Effects of Cash Transfers: Experimental Evidence From Kenya." *Econometrica* 90, no. 6 (2022): 2603–43. https://doi.org/10.3982/ECTA17945.

Evans, David, Stephanie Hausladen, Katrina Kosec, and Natasha Reese. *Community-Based Conditional Cash Transfers in Tanzania: Results from a Randomized Trial*. World Bank Publications, 2014.

Field, Erica, and Elisa M. Maffioli. "Are Behavioral Change Interventions Needed to Make Cash Transfer Programs Work for Children? Experimental Evidence from Myanmar." SSRN Scholarly Paper. Rochester, NY, December 2, 2021. https://doi.org/10.2139/ssrn.3584786.

Filmer, Deon, Jed Friedman, Eeshani Kandpal, and Junko Onishi. "Cash Transfers, Food Prices, and Nutrition Impacts on Ineligible Children." *The Review of Economics and Statistics* 105, no. 2 (March 3, 2023): 327–43. https://doi.org/10.1162/rest_a_01061.

Gertler, Paul. "Do Conditional Cash Transfers Improve Child Health? Evidence from PROGRESA's Control Randomized Experiment." *The American Economic Review* 94, no. 2 (2004): 336–41. https://www.jstor.org/stable/3592906.

Gertler, Paul J., Sebastian W. Martinez, and Marta Rubio-Codina. "Investing Cash Transfers to Raise Long-Term Living Standards." *American Economic Journal: Applied Economics* 4, no. 1 (January 2012): 164–92. https://doi.org/10.1257/app.4.1.164.

Hidrobo, Melissa, John Hoddinott, Amber Peterman, Amy Margolies, and Vanessa Moreira. "Cash, Food, or Vouchers? Evidence from a Randomized Experiment in Northern Ecuador," 2017. https://3ieimpact.org/sites/default/files/2018-12/lhachimi-replication-plan.pdf.

Hoddinott, John, Susanna Sandström, and Joanna Upton. "The Impact of Cash and Food Transfers: Evidence from a Randomized Intervention in Niger." American Journal of Agricultural Economics 100, no. 4 (2018): 1032–49. https://doi.org/10.1093/ajae/aay019.

Hoddinott, John, Emmanuel Skoufias, and Ryan Washburn. "The Impact of PROGRESA on Consumption: A Final Report," n.d.

Kansikas, Carolina, Anandi Mani, and Paul Niehaus. "Customized Cash Transfers: Financial Lives and Cash-Flow Preferences in Rural Kenya," n.d.

Levere, Michael, Gayatri Acharya, and Prashant Bharadwaj. "The Role of Information and Cash Transfers on Early Childhood Development." World Bank Group, 2016. https://documents1.worldbank.org/curated/en/788751483028902307/pdf/WPS7931.pdf.

Macleod, Marin, Sydney Piggott, Joudy Sarraj, and Nicoli Dos Santos Stiller. "How to Deliver Cash Transfer Programs More Effectively to Hard-to-Reach Populations (SSIR)," 2021. https://ssir.org/articles/entry/how_to_deliver_cash_transfer_programs_more_effectively_to_hard_to_reach_populations.

Macours, Karen, Norbert Schady, and Renos Vakis. "Cash Transfers, Behavioral Changes, and Cognitive Development in Early Childhood: Evidence from a Randomized Experiment." *American Economic Journal: Applied Economics* 4, no. 2 (April 1, 2012): 247–73. https://doi.org/10.1257/app.4.2.247.

Manley, James, Yarlini Balarajan, Shahira Malm, Luke Harman, Jessica Owens, Sheila Murthy, David Stewart, Natalia Elena Winder-Rossi, and Atif Khurshid. "Cash Transfers and Child Nutritional Outcomes: A Systematic Review and Meta-Analysis." *BMJ Global Health* 5, no. 12 (December 2020): e003621. https://doi.org/10.1136/bmjgh-2020-003621.

Margolies, Amy, and John Hoddinott. "Costing Alternative Transfer Modalities." *Journal of Development Effectiveness* 7, no. 1 (January 2, 2015): 1–16. https://doi.org/10.1080/19439342.2014.984745.

McIntosh, Craig, and Andrew Zeitlin. "Cash versus Kind: Benchmarking a Child Nutrition Program against Unconditional Cash Transfers in Rwanda." arXiv, June 1, 2021. http://arxiv.org/abs/2106.00213.

Paxson, Christina, and Norbert Schady. "Does Money Matter? The Effects of Cash Transfers on Child Development in Rural Ecuador." *Economic Development and Cultural Change* 59, no. 1 (October 2010): 187–229. https://doi.org/10.1086/655458.

Schwab, Benjamin. "In the Form of Bread? A Randomized Comparison of Cash and Food Transfers in Yemen." *American Journal of Agricultural Economics* 102, no. 1 (2020): 91–113. https://doi.org/10.1093/ajae/aaz048.

Téllez-Rojo, Martha M., Betty Manrique-Espinoza, Karla Moreno-Tamayo, Vanessa De la Cruz-Góngora, Gustavo Ángeles, and Aarón Salinas-Rodríguez. "Heterogeneous Impact of the Non-Contributory Pension Programme 70 y Más on Nutritional Status of the Elderly in Rural Mexico." *The Lancet* 381 (June 17, 2013): S143. https://doi.org/10.1016/S0140-6736(13)61397-5.

Weaver, Jeffrey, Sandip Sukhtankar, Paul Niehaus, and Karthik Muralidharan. "Cash Transfers for Child Development: Experimental Evidence from India." Working Paper. Working Paper Series. National Bureau of Economic Research, January 2024. https://doi.org/10.3386/w32093.

World Bank Group. "Closing the Gap : The State of Social Safety Nets 2017." Text/HTML, 2017. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/811281494500586712/Closing-the-gap-the-state-of-social-safety-nets-2017.

2. Graduation programs

Graduation or cash-plus programs are multifaceted interventions to improve access to self-employment activities. At the core of the model is a productive asset, typically livestock or cash transfers combined with different types of training. In some settings, these programs also offer access to healthcare, saving accounts, life skills coaching, cash or food support, and health or nutrition training (IPA, 2023). The theory of change behind these interventions is that simultaneously relaxing capital, skill, and psychological constraints can provide a "big push" to overcome the poverty trap. There is **great evidence** of the impact of graduation programs on incomes and food and nutrition security, though there is less evidence of their links to agricultural productivity or climate resilience because they are not often included as primary outcomes. There is also evidence that these programs can be highly cost-effective. Recent research isolating the effects of individual components offers additional insight into their design.

The core graduation program can significantly improve incomes and food security. In Bangladesh, where BRAC initially pioneered the model, graduation programs have had large and persistent effects on incomes, consumption, and savings (Bandiera et al., 2017; BRAC, 2023). These effects have later been replicated across the world. A six-country study in Ethiopia, Ghana, Honduras, India, Pakistan, and Peru also found that the standard graduation model - with slight local variations - led to higher per capita consumption, incomes, and savings (Banerjee et al., 2015). Beneficiaries also experienced less food insecurity and reported better physical and mental health, with effects persisting over time. In Afghanistan, the model increased per capita consumption by 30 percent and led to a 20 percentage point decline in the share of households below the poverty line (Bedoya et al., 2019).

Iterations of the model have also proven effective, though remain relatively untested at a larger scale. In Uganda, for example, an intervention that provided training, mentorship, and cash transfers-- instead of productive assets--had large positive effects on consumption, revenues, and nutrition (Sedlmayr et al., 2020). These effects held when a similar intervention was implemented in war-affected villages in the country (Blattman et al., 2016). The latter also found that providing group encouragement training led to further income increases. In Niger, incorporating a psychological intervention in addition to cash transfers led to large positive effects on off-farm business revenues (Bossuroy et al., 2022). In Zambia, a graduation program implemented by the government had large positive effects on consumption and income (Botea et al., 2023). In Côte d'Ivoire, however, a program with components to enhance social cohesion in a post-conflict setting saw only small effects (Marguerie and Premand, 2019). In Mozambique, an intervention that provided access to a mobile savings account similarly found weak effects (Batista and Vicente, 2020). During political crises and social upheaval in Yemen, treatment households saw moderate gains in savings and asset accumulation but null effects on consumption and income (Brune et al., 2022). In Ethiopia, a light-touch graduation program targeting households that benefited from the national social protection program had modest effects on assets but no effects on consumption. The same program in Ethiopia also reduced asset losses among households that experienced a drought (Hirvonen et al., 2023).

Adoption: Graduation programs have generally seen high adoption levels among beneficiaries, with some exceptions. In an experimental study in Ethiopia, Ghana, Honduras, Pakistan, and Peru, virtually

all households chosen for treatment enrolled in the program (Banerjee et al., 2015). In India, however, 35 percent of participants refused to participate. There is some evidence that behavioral barriers may have driven this trend. One group of villagers, for example, thought that the implementing partner was from a different religion and refused to accept livestock from them. Another group of wives feared that their husbands would mishandle the asset and embarrass their families in front of the village.

Cost-effectiveness: Highly cost-effective in a range of locations. Graduation programs tend to be highly cost-effective. The original program in Bangladesh had an average benefit-cost ratio of 5.4 and an estimated internal rate of return between 16 percent and 23 percent (Bandiera et al., 2017). The six-country study also found that benefits from the program exceeded costs in all countries except Honduras (Banerjee et al., 2015).1 In Bangladesh and India, consumption gains persisted in measurements conducted seven and ten years after the asset transfer, respectively (Bandiera et al. 2017; Banerjee et al. 2021). In Ethiopia, the benefits were approximately equal to the cost of the program, as the consumption gains attenuated seven years after the transfer, unlike in Bangladesh (Barker et al., 2023). In Kenya, the program had a benefit-cost ratio of 1.7 among pastoralists. In Uganda, the different variations of the program saw an internal rate of return of 3 to 24 percent (Sedlmayr et al., 2020; Blattman et al., 2016). Finally, evidence from Niger indicates that introducing graduation components to national cash transfer programs can yield benefits close to 20 times larger than the costs (Bossuroy et al., 2022).

Recent research isolating the effects of different components offers three insights for the design of cash-plus programs. First, training and coaching are important to the effectiveness of the model in several settings: in Ghana and Uganda, removing training significantly reduced the effects of other components (Banerjee et al., 2022; Sedlmayr et al., 2020). However, in Zambia, training and mentoring did not improve results compared to asset transfers alone (Botea et al., 2023). Second, supervision may be unnecessarily costly in some settings. Based on evidence from Uganda, encouraging participants to form self-help groups might be a cheaper and more effective accountability mechanism (Blattman et al., 2016). Third, preliminary evidence from Ghana suggests that introducing psychological modules - such as cognitive behavioral therapy (CBT) - could have downstream economic effects, even when delivered by nonspecialists (Barker et al., 2021).

Context: Graduation programs have been found to be effective across different contexts. The only exception might be conflict-affected regions, where the evidence is mixed. For example, positive findings from war-affected villages of Uganda contrast with small effects in post-conflict Côte d'Ivoire (Blattman et al., 2016; Marguerie and Premand, 2019). In Yemen, a graduation program faced significant challenges due to the political crisis and armed conflict of 2011 (Brune et al., 2022). This led to the suspension of consumption transfers. Regardless, the intervention led to increases in total assets, typically livestock, as well as savings, though the evaluation found null effects for consumption, income, and food security.

1 Assuming that gains in year 4 persist in perpetuity, the program in Honduras had a negative rate of return of 198 percent— possibly because many chickens (the asset transfer) died due to illness.

Bandiera, Oriana, Robin Burgess, Narayan Das, Selim Gulesci, Imran Rasul, and Munshi Sulaiman. "Labor Markets and Poverty in Village Economies*." *The Quarterly Journal of Economics* 132, no. 2 (May 1, 2017): 811–70. https://doi.org/10.1093/qje/qjx003.

Banerjee, Abhijit, Esther Duflo, Nathanael Goldberg, Dean Karlan, Robert Osei, William Parienté, Jeremy Shapiro, Bram Thuysbaert, and Christopher Udry. "The Ultra Poor Graduation Approach | IPA." Accessed June 11, 2024. https://poverty-action.org/impact/ultra-poor-graduation-approach.

Banerjee, Abhijit, Esther Duflo, Nathanael Goldberg, Dean Karlan, and Christopher Udry. "A Multifaceted Program Causes Lasting Progress for the Very Poor: Evidence from Six Countries | Science." Science, 2015. https://www.science.org/doi/10.1126/science.1260799.

Banerjee, Abhijit, Dean Karlan, Robert Darko Osei, Hannah Trachtman, and Christopher Udry. "Unpacking a Multi-Faceted Program to Build Sustainable Income for the Very Poor." *NBER Working Papers*, NBER Working Papers, February 2018. https://ideas.repec.org//p/nbr/nberwo/24271.html.

Barker, Nathan, Gharad T. Bryan, Dean Karlan, Angela Ofori-Atta, and Christopher R. Udry. "Mental Health Therapy as a Core Strategy for Increasing Human Capital: Evidence from Ghana." Working Paper. Working Paper Series. National Bureau of Economic Research, October 2021. https://doi.org/10.3386/w29407.

Batista, Catia, and Pedro C. Vicente. "Improving Access to Savings through Mobile Money: Experimental Evidence from African Smallholder Farmers." *IZA Discussion Papers*, IZA Discussion Papers, November 2019. https://ideas.repec.org//p/iza/izadps/dp12813.html.

Bedoya, Guadalupe, Aidan Coville, Johannes Haushofer, Mohammad Isaqzadeh, and Jeremy Shapiro. "Publication: No Household Left Behind: Afghanistan Targeting the Ultra Poor Impact Evaluation." Open Knowledge Repository, 2019. https://openknowledge.worldbank.org/entities/publication/6dbef0af-1682-5f56-a024-cd44accd6a47.

Blattman, Christopher, Eric P. Green, Julian Jamison, M. Christian Lehmann, and Jeannie Annan. "The Returns to Microenterprise Support among the Ultrapoor: A Field Experiment in Postwar Uganda." *American Economic Journal: Applied Economics* 8, no. 2 (April 2016): 35–64. https://doi.org/10.1257/app.20150023.

Bossuroy, Thomas, Markus Goldstein, Bassirou Karimou, Dean Karlan, Harounan Kazianga, William Parienté, Patrick Premand, et al. "Tackling Psychosocial and Capital Constraints to Alleviate Poverty." *Nature* 605, no. 7909 (May 2022): 291–97. https://doi.org/10.1038/s41586-022-04647-8.

BRAC. "Ultra-Poor Graduation." *BRAC* (blog). Accessed June 11, 2024. https://www.brac.net/program/ultra-poor-graduation/.

Brune, Alexander. "Multigrid Barrier and Penalty Methods for Large Scale Topology Optimization of Solid Structures." University of Birmingham, 2022. https://etheses.bham.ac.uk/id/eprint/12446/7/Brune2022PhD.pdf.

Hirvonen, Kalle, Daniel O. Gilligan, Jessica Leight, Heleene Tambet, and Victor Villa. Do ultra-poor graduation programs build resilience against droughts? Evidence from rural Ethiopia. Intl Food Policy Res Inst, 2023.

Marguerie, Alicia, and Patrick Premand. "Economic Inclusion, Micro-Entrepreneurship and Social Cohesion Experimental Evidence from Post-Conflict Côte d'Ivoire," 2019. https://conference.iza.org/conference_files/worldbank_2019/marguerie_a24306.pdf.

Sedlmayr, Richard, Anuj Shah, and Munshi Sulaiman. "Cash-plus: Poverty Impacts of Alternative Transfer-Based Approaches." *Journal of Development Economics* 144 (May 2020): 102418. https://doi.org/10.1016/j.jdeveco.2019.102418.

3. Seasonal migration

Models to facilitate seasonal migration aim to help households mitigate periods of hunger during the agricultural cycle (lean seasons) by encouraging temporary migration to areas with more job opportunities. Migrants remit earnings back to their homes, which can be used to improve food security among household members who remain in the home location. Migration from rural to urban areas can allow families to cope with shocks and smooth income and consumption (Mobarak and Reimão, 2020; Gröger and Zylberberg, 2016). There is **mixed evidence** for the potential of models to facilitate seasonal migration to improve food and nutrition security and household incomes, though much more limited evidence on agricultural outcomes or climate resilience. However, nearly all of the well-identified causal evidence on models to facilitate seasonal migration comes from Bangladesh, where features of rural transport infrastructure and urban labor markets might make this model particularly compelling. There is limited but promising evidence showing that these models can be cost-effective.

Interventions to incentivize seasonal migration can have strong effects on food security and incomes. In Bangladesh, providing a small transport subsidy to cover the roundtrip travel cost to nearby cities increased food security and caloric intake by migrants' families, moving people from a subsistence level of consumption to a comfortable level (Bryan et al., 2014). Also, in Bangladesh, a follow-up study that varied the proportion of the population eligible to receive subsidies found that when large numbers are induced to migrate, there are positive spillovers for the village economy (Akram et al., 2017). Not only do migrants earn more, but agricultural wages and hours worked also increase for those who do not migrate. This can slightly reduce profits for employers and increase the price of some foods. In Kenya, solely providing information about labor market conditions in the capital city increased migration, reported income, and financial well-being for migrants, though remittances, family savings, and food expenditure increased only modestly (Baseler, 2019). However, this intervention was not focused on seasonal migration specifically.

Adoption: Information seems to be a key constraint to seasonal migration. In Bangladesh, learning about the benefits of seasonal migration seems to be fairly individual and location-specific: friends' migration choices the previous year do not influence migration decisions, suggesting that people learn from their own experiences (Bryan et al., 2014). Migrants also tend to form a sustained connection with their urban employers. Incentives, such as subsidies, can allow individuals to learn about the benefits of migration and induce longer-term changes in migration behavior even after they are removed. Learning about the benefits of migration can also spill over within sending villages, suggesting there is value in increasing the density of incentives within a village (Akram et al., 2017). Evidence from Kenya shows that hidden income on the part of migrants generates sustained misinformation, which lowers local incentives to migrate (Baseler, 2019).

Liquidity is another key barrier to seasonal migration, but its relevance may depend on the context. For example, relaxing liquidity constraints during the lean season in Zambia had welfare benefits but did not induce migration (Fink et al., 2020). In China, instead, relaxing liquidity constraints did increase internal migration (Cai, 2020). Evidence from Bangladesh also underscores the importance of digital tools for facilitating remittances from migrants: introducing mobile money services to urban migrants and rural villages significantly increased calorie consumption among users of the service (Lee et al., 2021).

Cost-effectiveness: Mixed, cost-effectiveness depends on labor markets in receiving locations (i.e. urban areas) and no examples of implementation at scale. Interventions to facilitate seasonal migration can be cost-effective, provided that they are designed to address the right constraints. Evidence from Bangladesh suggests that transportation subsidies are at least five times as cost-effective as cash transfers at improving food security. However, the effects of solely providing information are mixed, based on contrasting evidence from Bangladesh and Kenya (Akram et al., 2017; Bryan et al., 2014; Baseler, 2019). The shutdown of *No Lean Season*, a large-scale program that offered travel subsidies for seasonal migration to poor rural laborers in Bangladesh, raises questions about the implementation and scalability of such interventions that require further research to be addressed (EA, 2019). Cost-effectiveness depends on labor market conditions in regions that receive migrants. In some locations, it may be difficult to forecast seasonal labor opportunities. If labor supply exceeds demand in a way that induces wages to fall, programs may no longer be effective.

Context: The evidence on providing incentives for seasonal migration is fairly limited and concentrated in a few countries. This limits the ability to draw comparisons across settings. However, within this limitation, providing information about migration opportunities can play a bigger role in affecting migration decisions when firsthand experience with migration is lower (Baseler, 2019). In settings where migration is more widespread, information may be best complemented with other types of incentives, such as subsidies. The effectiveness of seasonal migration may also vary with context. Setting the optimal transfer size is particularly important - a program in Indonesia increased total seasonal income only when it was set to target households on the margin of migrating rather than all households (Bryan et al., 2022). In practice, targeting marginal households may be difficult without testing transfer sizes in each location. Other promising innovations to reduce seasonal poverty include programs to mitigate liquidity constraints (1; 2) and interventions to improve food storage and savings (1; 2), which are described in other sections (Khandker et al., 2015; Fink et al., 2020; Aggarwal et al., 2018; Brander et al., 2021).

BIBLIOGRAPHY

Akram, Agha Ali, Shyamal Chowdhury, and Ahmed Mushfiq Mobarak. "Effects of Emigration on Rural Labor Markets." *NBER*, 2017. https://www.nber.org/system/files/working_papers/w23929/w23929.pdf.

Baseler, Travis. "Hidden Income and the Perceived Returns to Migration." *American Economic Journal: Applied Economics* 15, no. 4 (October 2023): 321–52. https://doi.org/10.1257/app.20210571.

Brander, Michael, Thomas Bernauer, and Matthias Huss. "Improved On-Farm Storage Reduces Seasonal Food Insecurity of Smallholder Farmer Households – Evidence from a Randomized Control Trial in Tanzania." *Food Policy* 98 (January 2021): 101891. https://doi.org/10.1016/j.foodpol.2020.101891.

Bryan, Gharad, Shyamal Chowdhury, and Ahmed Mushfiq Mobarak. "Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh." *Econometrica* 82, no. 5 (2014): 1671–1748. https://doi.org/10.3982/ECTA10489.

Bryan, Gharad, Shyamal Chowdhury, Ahmed Mushfiq Mobarak, Melanie Morten, and Joeri Smits. "Encouragement and Distortionary Effects of Conditional Cash Transfers," 2022.

Cai, Shu. "Migration under Liquidity Constraints: Evidence from Randomized Credit Access in China." *Journal of Development Economics* 142, no. C (2020). https://ideas.repec.org//a/eee/deveco/v142y2020ics0304387818308113.html.

evidence action. "We're Shutting Down No Lean Season, Our Seasonal Migration Program:…." Evidence Action, June 6, 2019. https://www.evidenceaction.org/newsroom/were-shutting-down-no-lean-season-our-seasonal-migration-program-heres-why.

Fink, Günther, B. Kelsey Jack, and Felix Masiye. "Seasonal Liquidity, Rural Labor Markets, and Agricultural Production." *American Economic Review* 110, no. 11 (November 2020): 3351–92. https://doi.org/10.1257/aer.20180607.

Gröger, André, and Yanos Zylberberg. "Internal Labor Migration as a Shock Coping Strategy: Evidence from a Typhoon." *American Economic Journal: Applied Economics* 8, no. 2 (April 2016): 123–53. https://doi.org/10.1257/app.20140362.

Khandker, Shahidur R., M. A. Baqui Khalily, and Hussain A. Samad. "Mitigating Seasonal Hunger with Microfinance in Bangladesh: How Does a Flexible Programme Compare with the Regular Ones?" *Journal of Development Effectiveness* 7, no. 1 (January 2, 2015): 23–42. https://doi.org/10.1080/19439342.2014.988166.

Lee, Jean N., Jonathan Morduch, Saravana Ravindran, Abu Shonchoy, and Hassan Zaman. "Poverty and Migration in the Digital Age: Experimental Evidence on Mobile Banking in Bangladesh." *American Economic Journal: Applied Economics* 13, no. 1 (January 2021): 38–71. https://doi.org/10.1257/app.20190067.

Mobarak, Ahmed Mushfiq, and Maira Emy Reimão. "Seasonal Poverty and Seasonal Migration in Asia." *Asian Development Review* 37, no. 1 (March 2020): 1–42. https://doi.org/10.1162/adev_a_00139.

4. Public work programs

Public work programs, in which governments guarantee employment for those seeking jobs, are among the most common anti-poverty programs in developing countries. These programs are meant to supplement incomes while improving public infrastructure. This approach is meant to self-target beneficiaries through work requirements, create a minimum wage by making the government the employer of last resort, and invest in public goods (Muralidharan et al. 2017). However, there is scarce rigorous evidence on the impacts of public works programs on nutrition, agricultural production outcomes, or climate resilience, though several recent studies have leveraged lotteries or phased rollouts of programs. Overall, there is **mixed evidence** on the impacts of public works programs on food and nutrition security and income.

India's National Rural Employment Guarantee Scheme (NREGS) guarantees 100 days of paid employment for households living in rural India–making it one of the largest social protection projects in the country. A randomized evaluation of reforms to NREGS in the state of Andhra Pradesh found the program reduced poverty by 26 percent and increased household earnings by 14 percent (Muralidharan et al., 2017). Income gains came primarily from increased private labor-market earnings, suggesting NREGS increased wages in the market overall. Non-experimental evidence suggests NREGS narrowed the gender wage gap, improved nutritional intake by 11 percent, and boosted private sector wages (Azam, 2012; Liu and Deininger, 2013; Imbert and Papp, 2015). Nonetheless, there seems to be large heterogeneity in the implementation of NREGS across states. The program might also have led to worse educational outcomes for older children, as the opportunity cost of attending school went up and reduced seasonal migration to cities (1; 2) (Sukhtankar, 2017; Imbert and Papp, 2016; Imbert and Papp, 2018).

A systematic review of public work programs in Africa, mostly based on non-experimental studies, found disappointing effects on income, consumption, and sustained employment (Beierl and Grimm, 2019). However, a randomized evaluation of a youth employment program in Cote d'Ivoire found limited impacts on the likelihood of employment but a shift towards wage jobs during the program with modest but sustained impacts on savings (Bertrand et al., 2021). In Malawi, a randomized evaluation of the government-operated Social Action Fund found no impacts on nutrition, fertilizer use, or wages (Beegle et al., 2017). A quasi-experimental study from Ethiopia found a small effect of a public works program on agricultural productivity (Gazeaud and Stephane, 2022).

Adoption: No studies specifically addressed targeting or adoption.

Cost-effectiveness: Mixed cost-effectiveness with more positive results from India compared to other contexts. Cost-effectiveness may also depend on how public works programs affect wages in local labor markets. There is mixed evidence on cost-effectiveness. One study in India shows the estimated gains exceed the amount of NREGS-related cash transfers given to participants on a per capita basis (Deininger and Liu, 2013). Another paper from Cote d'Ivoire, however, shows that the cost per participant is about 2 times the estimated direct earnings up to the endline (12 to 15 months after the program), even under improved targeting. Evidence suggests that public works programs may reduce targeting costs relative to

some other social protection programs, though some of the evidence suggests improving targeting could improve public works programs as well.

Context: Public works programs may be most appropriate where targeting costs are high or where supply-side interventions, such as worker training, are infeasible. Cash-for-work programs may also be more feasible to run in uncertain, unstable environments relative to other programs and can be expanded in the face of price shocks or other crises (Blattman and Ralston, 2015). In some contexts, public works programs that pay out one large lump-sum cash transfer may facilitate migration by alleviating liquidity constraints. For example, a cash-for-public-works program in Comoros had a sizable impact on international migration (Gazeaud et al., 2023).

In India, the positive impacts of NREGS were measured in the context of an improvement in the delivery of the program, which led to reduced leakage of funds, increased program earnings, and reduced payout delays (Muralidharan et al., 2017). Program implementation quality may have a large influence on the impact of these programs in particular.

Azam, Mehtabul. “The Impact of Indian Job Guarantee Scheme on Labor Market Outcomes: Evidence from a Natural Experiment,” n.d.

———. “The Impact of Indian Job Guarantee Scheme on Labor Market Outcomes: Evidence from a Natural Experiment,” n.d.

Beegle, Kathleen, Emanuela Galasso, and Jessica Goldberg. “Direct and Indirect Effects of Malawi’s Public Works Program on Food Security.” *Journal of Development Economics* 128 (September 1, 2017): 1–23. https://doi.org/10.1016/j.jdeveco.2017.04.004.

Beierl and Grimm. “Do Public Works Programmes Work,” 2019. https://socialprotection.org/sites/default/files/publications_files/GIZ%20-%20Policy%20Brief%20-%20Do%20Public%20Works%20Programmes%20Work.pdf.

Bertrand, Marianne, Bruno Crépon, Alicia Marguerie, and Patrick Premand. “Do Workfare Programs Live Up to Their Promises? Experimental Evidence from Cote D’Ivoire.” *NBER* Working Papers, 2021. https://www.nber.org/system/files/working_papers/w28664/w28664.pdf.

Blattman, Christopher, and Laura Ralston. “Generating Employment in Poor and Fragile States: Evidence from Labor Market and Entrepreneurship Programs.” SSRN Scholarly Paper. Rochester, NY, July 19, 2015. https://doi.org/10.2139/ssrn.2622220.

Deininger, Klaus, and Yanyan Liu. *Welfare and Poverty Impacts of Indias National Rural Employment Guarantee Scheme: Evidence from Andhra Pradesh*. Intl Food Policy Res Inst, 2013.

Gazeaud, Jules, Eric Mvukiyehe, and Olivier Sterck. “Cash Transfers and Migration: Theory and Evidence from a Randomized Controlled Trial.” *The Review of Economics and Statistics* 105, no. 1 (January 6, 2023): 143–57. https://doi.org/10.1162/rest_a_01041.

Gazeaud, Jules, and Victor Stephane. “Productive Workfare? Evidence from Ethiopia’s Productive Safety Net Program.” *American Journal of Agricultural Economics* 105, no. 1 (2023): 265–90. https://doi.org/10.1111/ajae.12310.

Imbert, Clément, and John Papp. “Costs and Benefits of Seasonal Migration: Evidence from India.” *University of Warwick*, 2018. https://wrap.warwick.ac.uk/100711/1/WRAP-costs-benefits-seasonal-migration-evidence-India-Imbert-2018.pdf.

———. “Labor Market Effects of Social Programs: Evidence from India’s Employment Guarantee.” *American Economic Journal: Applied Economics* 7, no. 2 (April 2015): 233–63. https://doi.org/10.1257/app.20130401.

———. “Short-Term Migration, Rural Public Works, and Urban Labor Markets: Evidence from India.” *Journal of the European Economic Association* 18, no. 2 (April 1, 2020): 927–63. https://doi.org/10.1093/jeea/jvz009.

Muralidharan, Karthik, Paul Niehaus, and Sandip Sukhtankar. “General Equilibrium Effects of (Improving) Public Employment Programs: Experimental Evidence from India.” Working Paper. Working Paper Series. National Bureau of Economic Research, September 2017. https://doi.org/10.3386/w23838.

Sukhtankar, Sandip. “India’s National Rural Employment Guarantee Scheme: What Do We Really Know about the World’s Largest Workfare Program?” *India Policy Forum* 13, no. 1 (2017): 231–85. https://econpapers.repec.org/article/ncancaerj/v_3a13_3ay_3a2017_3ai_3a2017-1_3ap_3a231-285.htm.

5. Adaptive social protection

Adaptive social protection refers to interventions that provide cash transfers to farmers and rural households in settings affected by weather shocks or seasonal disruptions to consumption. Social protection programs can also be offered in anticipation of climate events, often supplemented with disaster preparedness efforts. These measures empower participants to secure essential supplies before disasters, thereby enhancing household resilience. By strengthening households' capacity to withstand the effects of climate-induced shocks, social protection programs build resilience. There is **high potential evidence** of the impact of weather-responsive cash transfers on food and nutrition security, though the existing and emerging literature is promising. It is possible to consider evidence from settings affected by climate change, even if it does not test shock-responsive cash transfers specifically. Still, more research is needed to understand how to design these programs effectively.

In Nigeria, households that received transfers before a flood were less likely to resort to harmful coping strategies, such as missing meals, compared to similar households that received the transfer after a flood (Balana et al., 2023).

Non-experimental evidence shows that adaptive social protection has the potential to boost food security and incomes. In Kenya, the Hunger Safety Net Programme (HSNP) gives cash transfers to two groups of pastoralists. Every two months, 100,000 of the poorest households receive unconditional transfers. In times of drought, the program scales up and provides cash transfers to 250,000 additional beneficiaries. The program might have improved food expenditure, creditworthiness, and asset accumulation, generated a significant income multiplier, and reduced multidimensional poverty in regions where recurring droughts exacerbate chronic food insecurity in ultra-poor households (Oxford, 2018; Song and Imai, 2019). In Bangladesh, sending cash transfers to households about to experience severe flooding significantly improved food consumption and well-being (Pople et al., 2021). During floods, beneficiaries were 36 percent less likely to go a day without eating and more likely to evacuate household members and livestock, reducing asset loss and damage. Buffering effects on food consumption slowly dissipate if farmers get the transfer closer to the floods.

Indicative evidence from settings affected by climate change also supports the potential of climate-responsive cash transfers to improve outcomes of interest. In Niger, a government program providing small, unconditional, and regular cash transfers increased household consumption by 10.4 percent through savings and income smoothing, with effects concentrated in households affected by droughts (Premand and Stoeffler, 2020). Cash transfers allowed households to keep selling their production and mitigate the reduction of its value. In some cases, however, cash transfers alone may be insufficient. In Nicaragua, conditional cash transfers combined with vocational training or productive investment grants enabled households' consumption and income to be better protected against the negative impact of weather variability. In addition, for households eligible for the productive investment grant, there was a significant positive impact on consumption and income when the intensity of the shocks increased (Macours et al., 2022). Cash transfers alone, however, did not protect against future shocks.

Adoption: As noted here, ineffective targeting of conditional or means-tested transfer programs may limit the impact of cash transfer programs. More research is needed to understand how to effectively structure or design adaptive social protection in settings affected by climate shocks specifically.

Cost-effectiveness: Unclear but likely high cost-effectiveness. Coupled with accurate forecasts of weather events or other disasters, adaptive transfers are relatively inexpensive to send via mobile phones. While cash transfers can be cost-effective when appropriately designed (see here), there is no evidence supporting adaptive schemes. Indicative evidence from Niger shows that multi-year programming with predictable transfers is likely to be more effective than emergency relief in supporting livelihoods, given the critical importance of timing for agricultural investments (Premand and Stoeffler, 2020). However, more research is needed to better understand how to optimally design programs that respond specifically to emergencies. Anticipatory cash transfers may be more cost-effective than responsive transfers if forecasts are sufficiently accurate.

Context: The (limited) evidence available indicates that adaptive social protection can be effective across different contexts, including South Asia, East and West Africa, and Latin America. It also has the potential to benefit target groups. In Bangladesh, children in households that received transfers in anticipation of floods were three percentage points more likely to consume three or more meals three months after the transfers took place (Pople et al., 2021).

Macours, Karen, Patrick Premand, and Renos Vakis. "Transfers, Diversification and Household Risk Strategies: Can Productive Safety Nets Help Households Manage Climatic Variability?" *The Economic Journal* 132, no. 647 (October 1, 2022): 2438–70. https://doi.org/10.1093/ej/ueac018.

Oxford. "Evaluation of the Kenya Hunger Safety Net Programme Phase 2," 2018. https://www.opml.co.uk/files/Publications/a0013-evaluation-kenya-hunger-safety-net-programme/impact-evaluation-final-report-ex-summary.pdf?noredirect=1.

Pople, Ashley. "Anticipatory Cash Transfers in Climate Disaster Response." Accessed June 14, 2024. https://doi.org/10.1257/rct.6576-1.1.

Song, Sophie, and Katsushi S. Imai. "Does the Hunger Safety Net Programme Reduce Multidimensional Poverty? Evidence from Kenya." *Development Studies Research* 6, no. 1 (January 1, 2019): 47–61. https://doi.org/10.1080/21665095.2019.1582347.

Stoeffler, Quentin, and Patrick Premand. *Do Cash Transfers Foster Resilience? Evidence from Rural Niger*. World Bank, Washington, DC, 2020. https://doi.org/10.1596/1813-9450-9473.

6. Technical and vocational education and training

Technical and Vocational Education and Training (TVET) interventions encompass a wide variety of programs, including some elements of vocational education, apprenticeship, and hard and soft skills training, among other components (Haßler et al., 2020). TVETs aim to reduce unemployment and improve productivity across a range of occupations. Training is often provided by educational or professional institutions with curricula designed to teach skills tailored to the specific requirements of various trades. The goal is for trainees to gain skills and ease their entry into jobs. Multiple reviews point to mixed evidence on the impact of TVET in general (1; 2; McIntosh and Zeitlin 2022), but positive impacts on hours worked and earnings when combining practical experience, soft-skills training, and job referrals (J-PAL, 2023; Tripney et al., 2013). Programs typically increase workers' skills but only lead to increased income and employment in some cases. Entirely on-the-job training may be less effective (J-PAL 2023). A study in Nicaragua showed, however, that vocational training has a positive effect on consumption and reduces variability in income when accompanied by other interventions like conditional cash transfers (Macours et al., 2022). For example, training helped farmers during weather shocks to find wage employment in non-agricultural sectors and, therefore, smooth their income. While these reviews point to mixed results in the literature on TVET overall, there is **mixed evidence** of the impacts of TVET on complementary outcomes like income and employment and low evidence on agricultural productivity, food and nutrition security outcomes, and climate resilience. The primary channel for food and nutrition security (FNS) impacts would be through income and employment.

This review found no rigorous studies on Agricultural TVET programs specifically nor rigorous evaluations of nutritional or agricultural outcomes from TVET programs.

TVET programs might be likely to shift labor away from agriculture by providing skills and opportunities in other industries. However, some evidence has also shown no impact. In Kenya, an evaluation of a TVET program targeting youth found no statistically significant shift away from agricultural employment (Hamory Hicks et al. 2016). Similarly, in Uganda, a long-run follow-up of a TVET program showed that it increased hours worked, incomes, and non-durable consumption among program participants but did not reduce hours worked in agriculture (Blattman et al., 2014).

Cost-effectiveness: Unclear cost effectiveness in rural settings, depending on composition of labor markets and whether they train in skills that improve employment in urban settings. TVET interventions vary broadly in the components included in the design and the duration and intensity of the programming. As such, the cost of implementation will vary widely depending on the context.

Context: For outcomes outside of agriculture and nutrition, such as hours worked and earnings, vocational training programs may be most impactful when incorporating practical work experience with job placement support and when implemented with a focus on sectors with strong demand for labor (J-PAL, 2023). However, food security, nutrition, and agricultural outcomes have not been studied in detail.

Blattman, Christopher, Nathan Fiala, and Sebastian Martinez. "Generating Skilled Self-Employment in Developing Countries: Experimental Evidence from Uganda *." *The Quarterly Journal of Economics* 129, no. 2 (May 1, 2014): 697–752. https://doi.org/10.1093/qje/qjt057.

Center for Effective Global Action, University of California, Berkeley, Joan Hamory Hicks, Michael Kremer, Harvard University and National Bureau of Economic Research, Isaac Mbiti, University of Virginia, Edward Miguel, and University of California, Berkeley and National Bureau of Economic Research. "Evaluating the Impact of Vocational Education Vouchers on Out-of-School Youth in Kenya." 2016th ed. International Institute for Impact Evaluation, August 2016. https://doi.org/10.23846/ow1064.

Haßler, Björn, Gesine Haseloff, Taskeen Adam, S. Akoojee, Zoé Allier-Gagneur, S. Ayika, K. Bahloul, et al. "Technical and Vocational Education and Training in Sub-Saharan Africa: A Systematic Review of the Research Landscape." Zenodo, November 16, 2020. https://doi.org/10.5281/ZENODO.4264612.

JPAL. "Vocational and Skills Training Programs to Improve Labor Market Outcomes." The Abdul Latif Jameel Poverty Action Lab (J-PAL), March 14, 2023. https://www.povertyactionlab.org/policy-insight/vocational-and-skills-training-programs-improve-labor-market-outcomes.

Macours, Karen, Patrick Premand, and Renos Vakis. "Transfers, Diversification and Household Risk Strategies: Can Productive Safety Nets Help Households Manage Climatic Variability?" *The Economic Journal* 132, no. 647 (October 1, 2022): 2438–70. https://doi.org/10.1093/ej/ueac018.

Mcintosh, Craig, and Andrew Zeitlin. *Using Household Grants to Benchmark the Cost Effectiveness of a USAID Workforce Readiness Program*, 2020.

Tripney, Janice S, and Jorge G Hombrados. "Technical and Vocational Education and Training (TVET) for Young People in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis." *Empirical Research in Vocational Education and Training* 5, no. 1 (December 2013): 3. https://doi.org/10.1186/1877-6345-5-3.

7. Business training

This review focuses on business skills training for Micro, Small & Medium Enterprises (MSMEs) business owners, including training on bookkeeping, pricing, marketing, sales, goal-setting, and more. It covers the impacts of programs focused on MSMEs operating in rural areas or small towns. Improving management practices can improve overall profitability and enable entrepreneurs to expand their businesses and become more resilient to shocks. Taken together, there is **low evidence** for business skills training to improve household incomes in rural settings. More evidence is available from urban settings, which is not the primary focus of this review. There is no causal evidence of impacts on food security, nutrition, agricultural productivity, or climate resilience.

Business training can improve revenues for MSME owners, but there is no evidence tracing its impact on agricultural outcomes. Training female entrepreneurs in rural areas in Kenya, Mexico, and Pakistan increased revenues and profits (McKenzie and Puerto, 2021; Calderon et al., 2013; Giné and Mansuri, 2021). Participating firms consistently show improvements in business "quality" – improving dimensions like business practices and labor allocation. However, most evidence on business skills training focuses on urban firms. Households operating small businesses in urban areas are likely to face fundamentally different challenges concerning food security and nutrition and are unlikely to engage in agriculture.

Adoption: Several factors affect engagement in business training interventions, such as age, marital status, family size, previous participation in training programs, and distance to training venue - based on evidence from Kenya (McKenzie and Puerto, 2021). Attendance conditional on invitation to training varies by context, with 65 percent of invitees attending at least one training in Mexico and 93 percent attending in Pakistan (Calderon et al., 2013; Giné and Mansuri, 2021).

Cost-effectiveness: Mixed cost-effectiveness in rural settings. The evidence on the cost-effectiveness of business training is mixed. Business training was not cost-effective for a lender to offer in Pakistan, but the social benefits exceeded the costs of running the training (Giné and Mansuri, 2021). In Kenya, profit gains for training participants would need to last at least 1.5 years for the benefits to exceed the training costs (McKenzie and Puerto, 2021). In Mexico, business training appears highly cost-effective, with gains in average profits far outweighing the implementation costs of the program (Calderon et al., 2013).

Context: Contextual details can determine the success of business training. To reach rural firms, programs may need to conduct training in relatively remote areas or subsidize transport to help rural entrepreneurs participate. Work on business training in urban Kenya suggests that mentorship from a more experienced entrepreneur may be more effective than generic training (Brooks et al., 2018). Designing training programs for the context is important.

Brooks, Wyatt, Kevin Donovan, and Terence R. Johnson. "Mentors or Teachers? Microenterprise Training in Kenya." *American Economic Journal: Applied Economics* 10, no. 4 (October 2018): 196–221. https://doi.org/10.1257/app.20170042.

Calderon, Gabriela, Jesse M. Cunha, and Giacomo De Giorgi. "Business Literacy and Development: Evidence from a Randomized Controlled Trial in Rural Mexico." *Economic Development and Cultural Change* 68, no. 2 (January 2020): 507–40. https://doi.org/10.1086/701213.

Giné, Xavier, and Ghazala Mansuri. "Money or Management? A Field Experiment on Constraints to Entrepreneurship in Rural Pakistan." *Economic Development and Cultural Change* 70, no. 1 (October 2021): 41–86. https://doi.org/10.1086/707502.

McKenzie, David, and Susana Puerto. "Growing Markets through Business Training for Female Entrepreneurs: A Market-Level Randomized Experiment in Kenya." *American Economic Journal: Applied Economics* 13, no. 2 (April 2021): 297–332. https://doi.org/10.1257/app.20180340.

Financial services interventions

1. Agricultural credit

Several types of interventions aim to expand credit access among smallholder farmers, such as asset collateralized loans, credit for agricultural inputs, post-harvest loans, and emergency loans. This review focuses specifically on credit, rather than bundled interventions that include credit, which are the focus of another review. There is **mixed evidence** on the potential for credit to improve agricultural productivity, food and nutrition security, and incomes. There is promising evidence that loans can improve climate resilience. There is limited evidence on the cost-effectiveness of such interventions.

Evidence from Mali and Zambia suggests that expanding access to credit can improve agricultural output, in contrast to research in Bangladesh and Tanzania, which finds no impact on agricultural output, productivity, or profits (Beaman et al., 2014; Fink et al., 2020; Chowdhury et al., 2020; Nakano and Magezi, 2020). Research in Ethiopia, Mali, and Morocco finds that credit for agricultural inputs has no impact on food consumption or income, whereas research in Kenya and Zambia finds that small loans during the hungry season can significantly improve farmer revenues and food security outcomes (Tarozzi et al., 2015; Beaman et al., 2014; Crépon et al., 2015; Burke et al., 2019; Fink et al., 2020).

Loans increased household consumption only when paired with a saving product in Kenya (Mukherjee et al. 2021). Work in Bangladesh demonstrates that emergency loans in flood-prone areas can improve agricultural output and reduce food insecurity (Lane, 2022). These effects during negative climate shocks in Bangladesh indicate that emergency loans help farmers make less costly adaptation choices; they instead take high-risk but high-return investment decisions like expanding the land they rent and cultivate. Therefore, households hit by floods experience no reduction in their consumption levels (Lane, 2022). Relaxing collateral requirements for productive asset loans increases milk sales by Kenyan dairy farmers (Jack et al., 2023). These contrasting findings suggest an important role in understanding contextual details when designing credit programs.

Adoption: Much work on expanding agricultural credit finds low levels of adoption of loans, including 13 percent in Morocco, 19 percent in Bangladesh, and 21 percent in Mali (Crépon et al., 2015; Chowdhury et al., 2020; Beaman et al., 2014). However, the literature also demonstrates that well-designed products targeted to specific contexts can face much higher demand. Take-up of small loans during the hungry season in Zambia, for example, was almost universal (Fink et al., 2020). Evidence from Kenya demonstrates that restrictive collateral requirements substantially depress demand for loans (Jack et al., 2023). Work in Malawi finds that bundling credit with insurance can lower credit adoption, depending on the design and cost of the insurance, since limited liability credit can effectively function as implicit insurance without an explicit added cost (Giné and Yang, 2009). A study in Ghana, however, found that adding an insurance component that partially indemnified farmers against low crop prices made no difference in loan take-up (Karlan et al., 2011). However, the optimal uptake rate for a sustainable loan program is less than 100 percent unless it can perfectly target individuals who are likely to repay loans.

Cost-effectiveness: Unclear, likely high in some contexts. Recent examples implemented with partner organizations show promise for scale (BRAC in Bangladesh and Dairy Cooperatives in Kenya). Cost-effective-

ness will depend on take-up and implementation costs, which could imply relatively high marginal costs for each additional farmer. Given the low take-up of many microcredit interventions, costs to administer the programs are high. Even in a setting with high loan take-up, like Zambia, implementation costs exceed even high interest rates on short-term loans (Fink et al., 2020). However, in some limited cases, programs demonstrate high cost-effectiveness or financial sustainability, suggesting a path forward for program designers. In Bangladesh, emergency loans given in response to natural disasters improve lender profits (Lane, 2022). In Kenya, adopting an asset-collateralized model for loans for dairy farmers showed dramatic increases in demand with very high repayment rates across two rounds of loan offers, which allowed the program to cover costs and dramatically increase ownership of productive assets (Jack et al., 2023).

Context: Contextual details are key to designing effective credit interventions, as demonstrated by the wide range of effects on outcomes of interest and varying levels of adoption. Targeted, well-designed programs, such as post-harvest loans for crop farmers, emergency loans for farmers in flood-prone areas, or asset-collateralized loans for dairy farmers, all demonstrate high take-up and repayment rates. General expansions of traditional microfinance products to farmers are unlikely to prove similarly impactful in many contexts due to the timing of repayment, the size of loans, or other features that reduce both adoption and impacts. The impact evaluations cited are all from peaceful contexts, and the theory of change in fragile or conflict settings may be quite different.

Beaman, Lori, Dean Karlan, Bram Thuysbaert, and Christopher Udry. "Selection into Credit Markets: Evidence from Agriculture in Mali." Working Paper. Working Paper Series. National Bureau of Economic Research, August 2014. https://doi.org/10.3386/w20387.

Burke, Marshall, Lauren Falcao Bergquist, and Edward Miguel. "Sell Low and Buy High: Arbitrage and Local Price Effects in Kenyan Markets*." *The Quarterly Journal of Economics* 134, no. 2 (May 1, 2019): 785–842. https://doi.org/10.1093/qje/qjy034.

Chowdhury, Shyamal, Joeri Smits, and Qigang Sun. "Contract Structure, Time Preference, and Technology Adoption." SSRN Scholarly Paper. Rochester, NY, August 17, 2020. https://doi.org/10.2139/ssrn.3674311.

Crépon, Bruno, Florencia Devoto, Esther Duflo, and William Parienté. "Estimating the Impact of Microcredit on Those Who Take It Up: Evidence from a Randomized Experiment in Morocco." *American Economic Journal: Applied Economics* 7, no. 1 (January 2015): 123–50. https://doi.org/10.1257/app.20130535.

Fink, Günther, B. Kelsey Jack, and Felix Masiye. "Seasonal Liquidity, Rural Labor Markets, and Agricultural Production." *American Economic Review* 110, no. 11 (November 2020): 3351–92. https://doi.org/10.1257/aer.20180607.

Giné, Xavier, and Dean Yang. "Insurance, Credit, and Technology Adoption: Field Experimental Evidence-from Malawi." *Journal of Development Economics* 89, no. 1 (May 1, 2009): 1–11. https://doi.org/10.1016/j.jdeveco.2008.09.007.

Jack, William, Michael Kremer, Joost De Laat, and Tavneet Suri. "Credit Access, Selection, and Incentives in a Market for Asset Collateralized Loans: Evidence from Kenya - The Review of Economic Studies," February 16, 2023. https://www.restud.com/credit-access-selection-and-incentives-in-a-market-for-asset-collateralized-loans-evidence-from-kenya/, https://www.restud.com/credit-access-selection-and-incentives-in-a-market-for-asset-collateralized-loans-evidence-from-kenya/.

Karlan, Dean, Ed Kutsoati, Margaret McMillan, and Chris Udry. "Crop Price Indemnified Loans for Farmers: A Pilot Experiment in Rural Ghana." *Journal of Risk and Insurance* 78, no. 1 (2011): 37–55. https://doi.org/10.1111/j.1539-6975.2010.01406.x.

Lane, Gregory. "Adapting to Climate Risk with Guaranteed Credit: Evidence from Bangladesh," 2023.

Mukherjee, Sanghamitra, Lauren Falcao Bergquist, Marshall Burke, and Edward Miguel. "Unlocking the Benefits of Credit Through Saving." *NBER Working Papers*. Accessed June 17, 2024. https://www.nber.org/system/files/working_papers/w29542/w29542.pdf.

Nakano, Yuko, and Eustadius F. Magezi. "The Impact of Microcredit on Agricultural Technology Adoption and Productivity: Evidence from Randomized Control Trial in Tanzania." *World Development* 133 (September 2020): 104997. https://doi.org/10.1016/j.worlddev.2020.104997.

Tarozzi, Alessandro, Jaikishan Desai, and Kristin Johnson. "The Impacts of Microcredit: Evidence from Ethiopia." *American Economic Journal: Applied Economics* 7, no. 1 (January 2015): 54–89. https://doi.org/10.1257/app.20130475.

2. Insurance designed for farmers

Insurance products can be designed to target the needs and characteristics of small-scale farmers. The most common type in the literature is index insurance, designed to compensate farmers when a rainfall index shows low rainfall in the farmer's area. Others include livestock mortality insurance. These contracts vary in their level of protection and whether they cover the cost of inputs alone or compensate for lost revenues. By safeguarding against shocks, farmers can maintain a stable income to cover losses. This stability, in turn, creates opportunities for increased savings and financial security. Taken together, there is **mixed evidence** of the impact of heavily subsidized index insurance on agricultural productivity, food and nutrition security, and incomes. There is good evidence that index insurance can improve climate resilience (Lane, 2023). Despite its effectiveness when farmers have insurance, demand for insurance is too low at actuarially fair prices to sustain a commercial market, and there is mixed evidence (1, 2) on efforts to increase take-up (McIntosh et al., 2013; Cole et al. 2014).

Evidence from Bangladesh, Burkina Faso, China (1, 2), India, and Kenya (1, 2) demonstrate that insurance products can induce farmers to undertake higher-risk investments in livestock and rainfall-sensitive cash crops, whereas a commercial index insurance product failed to change investment practices in Ethiopia (Hill et al., 2019; Stoeffler et al, 2022; Liu et al., 2020; Cai et al., 2015; Cole et al., 2017; Jensen et al., 2017; Ahmed et al., 2020; Karlan et al. 2014; Bulte et al., 2020). Households that received insurance grants reported a lower incidence of food insecurity and higher agricultural revenue in Ghana (Karlan et al., 2014). In Bangladesh, Kenya, and India, households that adopted a hybrid index insurance product (which had triggers for both area yield and drought) and index-based livestock insurance, respectively, improved agricultural yields and income (Hill et al., 2019; Jensen et al., 2017; Mobarak and Rosenzweig, 2014). In Bangladesh, insurance payments resulted in increased use of irrigation to mitigate the yield impact of a long dry spell, and it also increased input expenditures and use and expanded crop area during the dry season (Hill et al., 2019). Livestock insurance also reduced costly coping strategies when faced with climate shocks, including livestock sales and skipping meals in Kenya (Janzen and Carter, 2019). For example, The index-based livestock insurance offered in Kenya reduced reliance on distress sales of livestock during droughts, and it allowed households to sell during non-shock seasons when livestock prices are high (Jensen et al., 2017)

Adoption: At market prices (above actuarially fair), insurance take-up is often quite low, as demonstrated in Kenya and Ethiopia (Ahmed et al., 2020; McIntosh et al., 2013). By contrast, in India, financial literacy training and a MoneyBack marketing strategy increased the demand for insurance by around 7 percentage points (Gaurav et al., 2011). Similarly, when farmers in Ghana and Ethiopia had a chance to learn about insurance and observe payouts through an initial grant or subsidy, demand was much higher, even at market prices (Karlan et al., 2014; Dercon et al., 2014). A key lesson that emerges in the literature is that delaying insurance premium payments can substantially increase adoption, as demonstrated in China, Ethiopia, and Kenya (Liu et al., 2020; Belissa et al., 2019; Casaburi and Willis, 2018). Providing insurance products at subsidized rates also has the potential to significantly increase adoption, as demonstrated in Bangladesh, where 87% of participants opted for a discounted insurance product (Hill et al. 2019).

Cost-effectiveness: Unclear, likely mixed. Few examples of studies implemented at scale with sustained financing sources. Group-based insurance could lower implementation and monitoring costs. Relatively high marginal cost per farmer. A key limitation that emerges from the literature is that, despite having large benefits for farmers when taken up, demand for insurance is low at actuarially fair prices. Evidence from China and India suggests positive net benefits despite a substantial public subsidy, and evidence from Kenya suggests livestock insurance has a positive benefit-cost ratio with respect to income (1.58) at the scale of the experiment and a very high benefit-cost ratio (44.1) when considering only the marginal cost of adding an additional participant (Cai, 2016; Ward et al., 2019; Jensen et al., 2017).

Context: The structure of premium pricing and the presence of basis risk are key contextual factors in evaluating the appropriateness of an insurance product for a given context. Reducing basis risk by using improved indices or offering hybrid products that cut across multiple risk factors for farmers may also improve both takeup and subsequent welfare outcomes. Evidence from Ethiopia also underscores that many rural communities informally insure each other, and index insurance can be complementary to within-group risk sharing (Dercon et al., 2014). In most cases, insurance products are structured to cover weather-related risks at a sub-national level and not catastrophic risks such as natural disasters that affect infrastructure or an entire country. Much of the evidence comes from private-sector-led programs, which are unlikely to be sustainable at scale at actuarially fair prices without long-run subsidies or government support. Many crop insurance programs in high-income countries are heavily subsidized by government support.

Ahmed, Shukri, Craig McIntosh, and Alexandros Sarris. "The Impact of Commercial Rainfall Index Insurance: Experimental Evidence from Ethiopia." *American Journal of Agricultural Economics* 102, no. 4 (2020): 1154–76. https://doi.org/10.1002/ajae.12029.

Belissa, Temesgen, Erwin Bulte, Francesco Cecchi, Shubhashis Gangopadhyay, and Robert Lensink. "Liquidity Constraints, Informal Institutions, and the Adoption of Weather Insurance: A Randomized Controlled Trial in Ethiopia." *Journal of Development Economics* 140, no. C (2019): 269–78. https://econpapers.repec.org/article/eeedeveco/v_3a140_3ay_3a2019_3ai_3ac_3ap_3a269-278.htm.

Cai, Hongbin, Yuyu Chen, Hanming Fang, and Li-An Zhou. "The Effect of Microinsurance on Economic Activities: Evidence from a Randomized Field Experiment." *The Review of Economics and Statistics* 97, no. 2 (May 1, 2015): 287–300. https://doi.org/10.1162/REST_a_00476.

Casaburi, Lorenzo, and Jack Willis. "Time versus State in Insurance: Experimental Evidence from Contract Farming in Kenya." *American Economic Review* 108, no. 12 (December 2018): 3778–3813. https://doi.org/10.1257/aer.20171526.

Cole, Shawn, Xavier Giné, and James Vickery. "How Does Risk Management Influence Production Decisions? Evidence from a Field Experiment." *The Review of Financial Studies* 30, no. 6 (June 1, 2017): 1935–70. https://doi.org/10.1093/rfs/hhw080.

Cole, Shawn, Daniel Stein, and Jeremy Tobacman. "Dynamics of Demand for Index Insurance: Evidence from a Long-Run Field Experiment." *American Economic Review* 104, no. 5 (May 2014): 284–90. https://doi.org/10.1257/aer.104.5.284.

Dercon, Stefan, Ruth Vargas Hill, Daniel Clarke, Ingo Outes-Leon, and Alemayehu Seyoum Taffesse. "Offering Rainfall Insurance to Informal Insurance Groups: Evidence from a Field Experiment in Ethiopia." *Journal of Development Economics* 106 (January 2014): 132–43. https://doi.org/10.1016/j.jdeveco.2013.09.006.

Gaurav, S., Cole, S., & Tobacman, J. (2011). Marketing Complex Financial Products in Emerging Markets: Evidence from Rainfall Insurance in India. Journal of Marketing Research, 48(SPL), S150-S162. https://doi.org/10.1509/jmkr.48.SPL.S150

Hill, Ruth Vargas, Neha Kumar, Nicholas Magnan, Simrin Makhija, Francesca De Nicola, David J. Spielman, and Patrick S. Ward. "Ex Ante and Ex Post Effects of Hybrid Index Insurance in Bangladesh." *Journal of Development Economics* 136 (January 2019): 1–17. https://doi.org/10.1016/j.jdeveco.2018.09.003.

Janzen, Sarah A, and Michael R Carter. "After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection - Janzen - 2019 - American Journal of Agricultural Economics - Wiley Online Library." *American Journal of Agricultural Economics*, 2018. https://onlinelibrary.wiley.com/doi/full/10.1093/ajae/aay061.

Jensen, Nathaniel, Christopher Barrett, and Andrew G. Mude. "Cash Transfers and Index Insurance: A Comparative Impact Analysis from Northern Kenya." *Journal of Development Economics* 129, no. C (2017): 14–28. https://econpapers.repec.org/article/eeedeveco/v_3a129_3ay_3a2017_3ai_3ac_3ap_3a14-28.htm.

Karlan, Dean, Robert Osei, Isaac Osei-Akoto, and Christopher Udry. "Agricultural Decisions after Relaxing Credit and Risk Constraints *." *The Quarterly Journal of Economics* 129, no. 2 (May 1, 2014): 597–652. https://doi.org/10.1093/qje/qju002.

Lane, Gregory. "Adapting to Climate Risk with Guaranteed Credit: Evidence from Bangladesh," n.d.

Liu, Yanyan, Kevin Chen, and Ruth V. Hill. "Delayed Premium Payment, Insurance Adoption, and Household

Investment in Rural China." *American Journal of Agricultural Economics* 102, no. 4 (2020): 1177–97. https://doi.org/10.1002/ajae.12038.

Lung, F. (2021). After 10 years in Kenya and Ethiopia, are we ready to scale up livestock insurance in the Horn of Africa?. News events. News. ILRI. https://www.ilri.org/news/after-10-years-kenya-and-ethiopia-are-we-ready-scale-livestock-insurance-horn-africa

McIntosh, Craig, Alexander Sarris, and Fotis Papadopoulos. "Productivity, Credit, Risk, and the Demand for Weather Index Insurance in Smallholder Agriculture in Ethiopia." *Agricultural Economics* 44, no. 4–5 (2013): 399–417. https://doi.org/10.1111/agec.12024.

Mobarak, Ahmed Mushfiq, and Mark Rosenzweig. "Risk, Insurance and Wages in General Equilibrium." Cambridge, MA: National Bureau of Economic Research, January 2014. https://doi.org/10.3386/w19811.

Stoeffler, Quentin, Michael Carter, Catherine Guirkinger, and Wouter Gelade. "The Spillover Impact of Index Insurance on Agricultural Investment by Cotton Farmers in Burkina Faso." *The World Bank Economic Review* 36, no. 1 (February 2, 2022): 114–40. https://doi.org/10.1093/wber/lhab011.

3. Savings groups

Collective action groups, such as savings or self-help groups (SHGs), are voluntary groups that meet regularly to facilitate savings and access to group-liability credit. Some of these groups, such as Village Savings and Loans Associations (VSLAs), combine savings, credit, and insurance products. Others, like Rotating Savings and Credit Associations (ROSCAs), encourage individuals to make cyclical contributions disbursed as a lump sum to one member in each cycle. Several interventions across different contexts have provided training and/or capital to encourage the formation of collective savings groups. Group members build social accountability which provides an enforcement mechanism of financial contributions to the savings pool. There is **mixed evidence** regarding the effects of these interventions on food and nutrition security, incomes, agricultural productivity, and climate resilience. Moreover, there is very limited evidence on the cost-effectiveness of these programs. Savings groups can be a means to reduce transaction costs for other interventions.

Interventions to promote the formation of collective action groups can increase savings but don't seem to have consistent effects on food security and income. In Cambodia, a program that provided training and grants to individuals to form their own SHGs found no effects on household expenditure, food security, or agricultural production - though it increased savings and livestock production (Ban et al., 2020). In Bihar, India, providing SHGs with seed capital for low-interest-rate loans had no effects on consumption, but it increased disposable income among beneficiaries as it reduced indebtedness to pricier informal lenders (Hoffman et al., 2021). In Mali, providing technical support to savings groups did lead to significant improvements in food security, the value of agricultural output, and consumption smoothing (Beaman et al., 2014). Similarly, in Malawi, promoting the creation of VSLAs through training improved food security and consumption but had mixed effects on income, with positive outcomes concentrated among business owners (Ksoll et al., 2016).

A program in Peru did not increase income or consumption but showed some evidence that households had higher resilience against idiosyncratic shocks (Frisancho and Valdivia, 2021). Evidence from Ghana, Malawi, Uganda, and India indicates that collective action groups can have positive effects on female empowerment (Karlan et al., 2017; Desai and Joshi, 2013). Collective groups in India, the Self-Employed Women's Association, acted as a buffer to reduce the impact of a drought that reduced monsoon crops and, thus, agricultural income. Members reported no significant change in income and were more likely to have a non-agricultural job (Desai and Joshi, 2013). Several systematic reviews have found that SHGs have positive effects on women's economic and political empowerment, control over family planning, and maternal and newborn health outcomes - though several of the studies do not meet the inclusion criteria of this review (Brody et al., 2017; Prost et al., 2013).

Adoption: Evidence from Kenya indicates that introducing a simple technology like a lockbox, which allowed individuals to increase investments in preventative health and be less vulnerable to shocks, had relatively high take-up at ~66 percent (Dupas and Robinson, 2013). However, social commitment may more effectively induce savings among present-biased individuals. In Uganda, a program that varied the income level of members found that groups with poorer members, where funds accumulate at a slower rate over

time, can limit beneficiaries' ability to borrow (Burlando and Canidio, 2017). This suggests a trade-off between the ability of savings groups to be financially inclusive and to effectively serve the credit needs of their members. In Mali, encouraging the formation of flexible groups - relative to ROSCAs - resulted in higher take-up (Beaman et al., 2014). It can be challenging to target households for participation, only 24 percent of households joined savings groups during a random program roll-out in Peru (Frisancho and Valdivia, 2021).

Cost-effectiveness: Unclear, likely mixed cost effectiveness depending on the structure of savings groups and the monitoring costs. There is very limited evidence on the cost-effectiveness of interventions to promote collective action groups. A multi-country study reported that the cost of encouraging VSLAs varied from $7 per household in Malawi to $11 in Uganda (Karlan et al., 2017). Introducing incentives for group leaders could improve the cost-effectiveness of such interventions by underwriting operating costs with fees. In Kenya, Tanzania, and Uganda, for example, a program trained Private Service Providers (PSPs) who received remuneration as a share of membership fees, and the fee structure attracted more entrepreneurial members (Greaney et al., 2016).

Context: Several factors can influence the effectiveness of collective action groups, such as pre-existing levels of participation in savings groups and the penetration and cost of informal lenders or informal insurance. In Mali, most adopters were members of ROSCAs compared to non-adopters and were more likely to have taken a loan before intervention (Beaman et al., 2014). In Bihar, India, SHGs helped beneficiaries reduce their debt burden by accessing loans at a 2 percent interest rate, a substantially cheaper alternative to informal lenders who typically charge 12 to 150 percent annual interest rates (Hoffman et al., 2021). Nonetheless, the effects of these interventions are mixed across different settings and even within the same country.

Ban, Radu, Michael J. Gilligan, and Matthias Rieger. "Self-Help Groups, Savings and Social Capital: Evidence from a Field Experiment in Cambodia." *Journal of Economic Behavior & Organization* 180 (December 1, 2020): 174–200. https://doi.org/10.1016/j.jebo.2020.09.029.

Beaman, Lori, Dean Karlan, and Bram Thuysbaert. "Saving for a (Not so) Rainy Day: A Randomized Evaluation of Savings Groups in Mali." Working Paper. Working Paper Series. National Bureau of Economic Research, October 2014. https://doi.org/10.3386/w20600.

Brody, Carinne, Thomas de Hoop, Martina Vojtkova, Ruby Warnock, Megan Dunbar, Padmini Murthy, and Shari L. Dworkin. "Can Self-Help Group Programs Improve Women's Empowerment? A Systematic Review." *Journal of Development Effectiveness* 9, no. 1 (January 2, 2017): 15–40. https://doi.org/10.1080/19439342.2016.1206607.

Burlando, Alfredo, and Andrea Canidio. "Does Group Inclusion Hurt Financial Inclusion? Evidence from Ultra-Poor Members of Ugandan Savings Groups." *Journal of Development Economics* 128 (May 1, 2017). https://doi.org/10.1016/j.jdeveco.2017.05.001.

Desai, Raj M., and Shareen Joshi. "Collective Action and Community Development: Evidence from Self-Help Groups in Rural India." *The World Bank Economic Review* 28, no. 3 (January 1, 2014): 492–524. https://doi.org/10.1093/wber/lht024.

Dupas, Pascaline, and Jonathan Robinson. "Why Don't the Poor Save More? Evidence from Health Savings Experiments," 2011. https://www.nber.org/system/files/working_papers/w17255/w17255.pdf.

Frisancho, Veronica, and Martin Valdivia. "Savings Groups Reduce Vulberability but Have Mixed Effect on Financial Inclusion." workingPaper. CAF, January 8, 2021. https://scioteca.caf.com/handle/123456789/1678.

Karlan, Dean, Beniamino Savonitto, Bram Thuysbaert, and Christopher Udry. "Impact of Savings Groups on the Lives of the Poor." *Proceedings of the National Academy of Sciences* 114, no. 12 (March 21, 2017): 3079–84. https://doi.org/10.1073/pnas.1611520114.

Ksoll, Christopher, Helene Bie Lilleør, Jonas Helth Lønborg, and Ole Dahl Rasmussen. "Impact of Village Savings and Loan Associations: Evidence from a Cluster Randomized Trial." *Journal of Development Economics* 120 (May 1, 2016): 70–85. https://doi.org/10.1016/j.jdeveco.2015.12.003.

Magnan, Nicholas, Vivian Hoffmann, Gissele Gajate, Daniel Kanyam, and Nelson Opoku. "Information, Technology, and Market Rewards: Incentivizing Aflatoxin Control in Ghana." *Journal of Development Economics* 151 (February 1, 2021): 102620. https://doi.org/10.1016/j.jdeveco.2020.102620.

Prost, Audrey, Tim Colbourn, Nadine Seward, Kishwar Azad, Arri Coomarasamy, Andrew Copas, Tanja A. J. Houweling, et al. "Women's Groups Practising Participatory Learning and Action to Improve Maternal and Newborn Health in Low-Resource Settings: A Systematic Review and Meta-Analysis." *Lancet (London, England)* 381, no. 9879 (May 18, 2013): 1736–46. https://doi.org/10.1016/S0140-6736(13)60685-6.

Governance interventions

1. Payments for ecosystems services

Payments for Ecosystems Services (PES) describes any program that provides incentives for farmers or landholders for activities that support sustainable ecosystems - including forest cover, indigenous plants and animals, or waterways. PES programs usually target households to protect private land but can also be structured for communities or groups to protect shared parcels. Payments and incentives can be structured to either support the planting of new trees or indigenous plants or to prevent new deforestation and land clearing. PES participants agree to preserve forest cover in specified areas while maintaining flexibility in land management elsewhere on their property. The financial incentives provided through PES compensate for the opportunity costs associated with afforestation and land management. Overall, there is **mixed evidence** that PES are efficient at improving food and nutrition security, agricultural productivity, and income. There is good evidence that PES promotes climate resilience by limiting deforestation and improving economic well-being, particularly for poorer households, but there is some evidence of deforestation leakage to non-participating parcels.

PES programs have been effective in limiting deforestation and cropland conversion in Mexico, Uganda, and China (Sims and Alix-Garcia, 2017; Jayachandran et al., 2017; Zheng et al., 2013). In India, a PES program was successful at reducing crop residue burning and improving air pollution (Jack et al., 2023). These changes, in turn, have resulted in additional ecosystem services; for instance, cropland conversion in China from flood-irrigated rice land to dryland resulted in improvements in water quality, quantity, and yield for downstream communities (Zheng et al., 2013). One concern with PES programs is how to structure contracts and monitoring systems to address compliance so that they incentivize uptake while minimizing leakage. Leakage occurs when landholders protect some parts of their land but increase clearing on other unprotected parcels, as in Malawi, where an increase in planted trees was accompanied by a substitution of previously unused land for the land under the tree planting contract (Jack and Santos, 2017). A program in Burkina Faso improved consumption and food security, especially when payments were timed to coincide with the lean season (Adjognon et al., 2021). However, evidence about the impact on livelihoods and income is limited and has mixed results in Malawi and Uganda, where poorer households appeared to benefit more (Jack and Santos, 2017; Jayachandran et al., 2017).

Adoption: In general, participation in PES schemes is voluntary. In Mexico, landowners tended to enroll parcels of land with the lowest opportunity cost—and thus the lowest commercial value (Sims and Alix-Garcia, 2017). In Uganda, only 32 percent of eligible households enrolled in the program (Jayachandran et al., 2017). The Ugandan program benefited poorer households more than wealthier households because the cost of labor was lower, but poorer households were slightly less likely to enroll. It illustrates that it can be difficult to calibrate the payments so that a sufficient number of households enroll and that the unknown compliance costs may deter households with the highest potential benefits.

Cost-effectiveness: This may be a highly cost-effective means to conserve land, but not necessarily targeted for poverty alleviation. Likely to become more cost-effective if satellite monitoring costs decrease.

Analyses of cost-effectiveness depend on how averted emissions or pollution are valued and the relative gains for households. There is stronger evidence that programs are cost-effective at averting emissions when considering program administrative costs. Many PES programs are not structured to improve income but rather to compensate participants for lost income from newly protected land (Jayachandran, 2023). Importantly, no paper found a negative effect on consumption, which is theoretically possible if payments are too low to offset the short-run opportunity cost of exploiting the land. Improving food security and consumption would require PES payments to be higher than the opportunity cost of land, which highlights a tradeoff between reaching more people and improving welfare among a smaller subset of landowners. In Burkina Faso, a 100 CFA payment led to a 22.5 CFA weekly increase in consumption expenditures (Adjognon et al., 2021). Depending on the goal of the program, it could be socially efficient to increase the number of participants protecting environmental resources rather than improving the private welfare of participants, who may be better served by unconditional anti-poverty programs.

Context: Mexico (1, 2) offers an example of a long-term program to develop national parks and support the water supply (Alix-Garcia et al., 2015; Sims and Alix-Garcia, 2017). Individual and communal landowners register specific parcels of their land for protection, with the understanding that they are free to develop other unenrolled parcels. In that case, leakage is an explicit feature of the policy rather than an unintended consequence. Programs like those administered in Mexico may be suitable for other locations with communal rights and/or in settings where specific portions of watersheds or natural areas are being protected since it lowers monitoring costs. When programs target geographically dispersed parcels, the monitoring and enforcement costs may be too high, although costs are decreasing with the availability of satellite imagery. The extent of leakage likely varies with the opportunity costs of land. There was no evidence of leakage in the Uganda program, which targeted a region with high rates of deforestation to harvest timber and charcoal for domestic markets. Other contexts where land has high commercial value, such as for cattle grazing or export commodities, may face a higher incentive to divert deforestation to other parcels (Jayachandran et al., 2017).

There is evidence in China that migration remittances increased to compensate for lower earnings from agricultural activities (Zheng et al., 2013). Similar programs in settings with fewer migration opportunities might result in worse outcomes for participants. In Malawi, participants who bid on PES contracts via willingness-to-pay auctions had less leakage than participants who were randomly assigned contracts, but there were no differences in consumption across groups (Kelsey and Santos, 2017). There is not enough evidence about which types of households uptake PES contracts to assess the extent to which contract design affects participation across a range of contexts.

Adjognon, Guigonan S., Daan van Soest, and Jonas Guthoff. "Reducing Hunger with Payments for Environmental Services (PES): Experimental Evidence from Burkina Faso." *American Journal of Agricultural Economics* 103, no. 3 (2021): 831–57. https://doi.org/10.1111/ajae.12150.

Alix-Garcia, Jennifer M., Katharine R. E. Sims, and Patricia Yañez-Pagans. "Only One Tree from Each Seed? Environmental Effectiveness and Poverty Alleviation in Mexico's Payments for Ecosystem Services Program." *American Economic Journal: Economic Policy* 7, no. 4 (November 2015): 1–40. https://doi.org/10.1257/pol.20130139.

Jack, B Kelsey, Seema Jayachandran, Namrata Kala, and Rohini Pande. "Money (Not) to Burn: Payments for Ecosystem Services to Reduce Crop Residue Burning," n.d.

Jack, Brian Kelsey, and Elsa Cardona Santos. "The Leakage and Livelihood Impacts of PES Contracts: A Targeting Experiment in Malawi." *Land Use Policy: The International Journal Covering All Aspects of Land Use*, no. 63 (2017): 645–58. https://dialnet.unirioja.es/servlet/articulo?codigo=5917563.

Jayachandran, Seema. "The Inherent Trade-Off Between the Environmental and Anti-Poverty Goals of Payments for Ecosystem Services," n.d.

Jayachandran, Seema, Joost de Laat, Eric F. Lambin, Charlotte Y. Stanton, Robin Audy, and Nancy E. Thomas. "Cash for Carbon: A Randomized Trial of Payments for Ecosystem Services to Reduce Deforestation." *Science* 357, no. 6348 (July 21, 2017): 267–73. https://doi.org/10.1126/science.aan0568.

Sims, Katharine R. E., and Jennifer M. Alix-Garcia. "Parks versus PES: Evaluating Direct and Incentive-Based Land Conservation in Mexico." *Journal of Environmental Economics and Management* 86, no. C (2017): 8–28. https://ideas.repec.org//a/eee/jeeman/v86y2017icp8-28.html.

Zheng, Hua, Brian E. Robinson, Yi-Cheng Liang, Stephen Polasky, Dong-Chun Ma, Feng-Chun Wang, Mary Ruckelshaus, Zhi-Yun Ouyang, and Gretchen C. Daily. "Benefits, Costs, and Livelihood Implications of a Regional Payment for Ecosystem Service Program." *Proceedings of the National Academy of Sciences* 110, no. 41 (October 8, 2013): 16681–86. https://doi.org/10.1073/pnas.1312324110.

2. Land tenure governance

Land tenure and land governance are the systems and procedures for establishing the rights of people in relation to land and other natural resources, including both formal and informal institutions (FAO, 2002). Land tenure programs may also define the rights of other community members or groups by documenting usage rights, access rights, and customary tenure arrangements. Land tenure regularization intends to help small-scale producers by clarifying property rights and enabling farmers to make long-term investments (World Bank, 2020). Most evidence on land tenure focuses on evaluating the impact of large-scale government-implemented policy changes or programs that encourage people to obtain land titles within an existing system. There is **high potential evidence** on the impacts of land tenure governance programs on agricultural productivity and income, with limited direct evidence on climate resilience. Evidence suggests that titling improves investments via tenure security rather than access to financial markets. Subsidizing women to participate in titling can meaningfully improve women's access to and control over land resources. There is a lack of evidence on nutrition, likely because nutrition status is not often a target outcome for this category of interventions.

A systematic review of land tenure programs and policies across Latin America, Africa, and Asia found that agricultural investment and land rentals increased. Still, there is little evidence that land titling translates into access to credit (Lawry et al., 2014). A series of studies on land titling reform from Ethiopia (1, 2, 3, and 4), Rwanda, Benin, and Zambia find that agricultural investment, including soil and water conservation measures and land rentals increased with no significant change in agricultural productivity (Holden et al. 2009; Deininger et al., 2011; Deininger et al., 2017; Deininger et al., 2008; Ali et al., 2014; Goldstein et al., 2018; Smith 2004). Evidence from a pilot land registration program in Ghana shows no effect on agricultural investment and productivity and a small reduction in agricultural production. Changes in wealth come from higher-return off-farm work (Agyei-Holmes et al., 2020). A long-run study in Madagascar of farmers with multiple plots with varying degrees of tenure security shows slight improvements in productivity and no difference in investment (Jacoby and Minten 2007). Tenure security reduced deforestation and forest fires in an experiment in Benin (Wren-Lewis et al., 2020). A similar finding is supported by a meta-analysis of 36 publications linking tenure security with forest cover (Robinson et al., 2014).

Some interventions encourage rental markets so that land can more easily be rented by productive tenants. Programs that subsidized farmers in Uganda and Kenya to participate in tenancy contracts or rental markets showed that agricultural productivity improved and household consumption increased (Burchardi et al., 2019; Acampora et al., 2022).

Land titling reforms have the potential to change local economic conditions by asserting individual rights over parcels of land and require large-scale investment from governments. As a result, most assessments of land reform programs rely on quasi-experimental strategies or use panel data to make inferences about the effects of land reform. The relatively few experimental studies show a promising link between tenure and women's empowerment and land investment (including forest cover). Land tenure has been linked to higher rates of migration in Mexico (de Janvry et al., 2015). More evidence on rental markets could help establish whether results from Uganda and Kenya generalize to other contexts (Burchardi et al., 2019; Acampora et al., 2022).

Adoption: Subsidies and information awareness campaigns have been effective at increasing the uptake of titling in Tanzania, Rwanda, and Uganda, particularly for women who have historically been excluded from formal and customary titling regimes (Ali et al., 2016; Ali et al., 2015; Habyarimana et al., 2019). This suggests that pecuniary and non-pecuniary costs (such as navigating administrative requirements) hinder broad-scale access to land titles. Once titles are granted, there is limited evidence that titles increase access to credit or consistently enable farmers to improve agricultural productivity (World Bank, 2020). Even if credit were widely available, farmers may be hesitant to offer land as collateral on loans or credit.

Cost-effectiveness: Mixed. Evidence is available only from Ethiopia, where the intervention was relatively cost-effective. This could be more cost-effective for other outcomes not considered in the review–such as women's empowerment and land investment. Land titling programs can be expensive to administer due to expenses associated with mapping remote regions and setting up administrative offices. Ethiopia's land titling program was a relatively cost-effective program that encouraged rapid titling and then empowered local land councils to settle disputes in a way that was not biased against poorer households (Deininger et al., 2008). Digital technologies lower the administrative costs associated with initiating land titling programs and with ongoing costs. USAID has implemented several programs using digital support tools for participatory mapping and titling, but there are no publicly available research publications meeting our inclusion criteria (USAID).

Context: Tension between collective and individual rights can generate overlapping claims to land and resources. This kind of uncertainty weakens the signal from titled land and diminishes the ability of title-holders to feel confident in their ownership since they may fear expropriation by local elites, as suggested by a case study in Ghana (Goldstein and Udry, 2008).

Acampora, Michelle, Lorenzo Casaburi, and Jack Willis. “Land Rental Markets: Experimental Evidence from Kenya.” Working Paper. Working Paper Series. National Bureau of Economic Research, September 2022. https://doi.org/10.3386/w30495.

Ali, Daniel Ayalew, Matthew Collin, Klaus Deininger, Stefan Dercon, Justin Sandefur, and Andrew Zeitlin. “Small Price Incentives Increase Women’s Access to Land Titles in Tanzania.” *Journal of Development Economics* 123, no. C (2016): 107–22. https://ideas.repec.org//a/eee/deveco/v123y2016icp107-122.html.

Ali, Daniel Ayalew, Klaus Deininger, and Markus Goldstein. “Environmental and Gender Impacts of Land Tenure Regularization in Africa: Pilot Evidence from Rwanda.” *Journal of Development Economics* 110 (September 2014): 262–75. https://doi.org/10.1016/j.jdeveco.2013.12.009.

Burchardi, Konrad B, Selim Gulesci, Benedetta Lerva, and Munshi Sulaiman. “Moral Hazard: Experimental Evidence from Tenancy Contracts*.” *The Quarterly Journal of Economics* 134, no. 1 (February 1, 2019): 281–347. https://doi.org/10.1093/qje/qjy023.

Cherchi, Ludovica, Markus Goldstein, James Habyarimana, Joao Montalvao, Michael O’Sullivan, and Chris Udry. “Incentives for Joint Land Titling: Experimental Evidence from Uganda,” n.d.

Deininger, Klaus, Daniel Ayalew Ali, and Tekie Alemu. *Assessing The Functioning Of Land Rental Markets In Ethiopia*. Policy Research Working Papers. The World Bank, 2008. https://doi.org/10.1596/1813-9450-4442.

———. “Impacts of Land Certification on Tenure Security, Investment, and Land Market Participation: Evidence from Ethiopia.” *Land Economics* 87, no. 2 (May 1, 2011): 312–34. https://doi.org/10.3368/le.87.2.312.

Deininger, Klaus, Fang Xia, and Stein Holden. “Gender-Differentiated Impacts of Tenure Insecurity on Agricultural Performance in Malawi’s Customary Tenure Systems.” SSRN Scholarly Paper. Rochester, NY, January 18, 2017. https://papers.ssrn.com/abstract=2901755.

FAO. “3. WHAT IS LAND TENURE,” 2002. https://www.fao.org/4/y4307e/y4307e05.htm.

Ferrara,Eliana, Ali, Daniel,Deininger,Klaus W. ,Goldstein,Markus P. ,La. “Empowering Women through Land Tenure Regularization : Evidence from the Impact Evaluation of the National Program in Rwanda.” Text/HTML. World Bank. Accessed June 18, 2024. https://doi.org/10/Empowering-women-through-land-tenure-regularization-evidence-from-the-impact-evaluation-of-the-national-program-in-Rwanda.

Goldstein, Markus, Kenneth Houngbedji, Florence Kondylis, Michael O’Sullivan, and Harris Selod. “Formalization without Certification? Experimental Evidence on Property Rights and Investment.” *Journal of Development Economics* 132, no. C (2018): 57–74. https://econpapers.repec.org/article/eeedeveco/v_3a132_3ay_3a2018_3ai_3ac_3ap_3a57-74.htm.

Goldstein, Markus, and Christopher Udry. “The Profits of Power: Land Rights and Agricultural Investment in Ghana.” *Journal of Political Economy*, 2008. https://doi.org/10.1086/595561.

Holden, Stein T., Klaus Deininger, and Hosaena Ghebru. “Impacts of Low-Cost Land Certification on Investment and Productivity.” *American Journal of Agricultural Economics* 91, no. 2 (2009): 359–73. https://doi.org/10.1111/j.1467-8276.2008.01241.x.

Jacoby, Hanan G., and Bart Minten. “Is Land Titling in Sub-Saharan Africa Cost-Effective? Evidence from Madagascar.” *The World Bank Economic Review* 21, no. 3 (January 1, 2007): 461–85. https://doi.org/10.1093/wber/lhm011.

Janvry, Alain de, Kyle Emerick, Marco Gonzalez-Navarro, and Elisabeth Sadoulet. “Delinking Land Rights from Land Use: Certification and Migration in Mexico.” *American Economic Review* 105, no. 10 (October 2015): 3125–49. https://doi.org/10.1257/aer.20130853.

Lawry, Steven, Cyrus Samii, Ruth Hall, Aaron Leopold, Donna Hornby, and Farai Mtero. "The Impact of Land Property Rights Interventions on Investment and Agricultural Productivity in Developing Countries: A Systematic Review." *Campbell Systematic Reviews* 10, no. 1 (2014): 1–104. https://doi.org/10.4073/csr.2014.1.

Robinson, Brian E., Margaret B. Holland, and Lisa Naughton-Treves. "Does Secure Land Tenure Save Forests? A Meta-Analysis of the Relationship between Land Tenure and Tropical Deforestation." *Global Environmental Change* C, no. 29 (2014): 281–93. https://doi.org/10.1016/j.gloenvcha.2013.05.012.

Smith, Robert E. "Land Tenure, Fixed Investment, and Farm Productivity: Evidence from Zambia's Southern Province." *World Development* 32, no. 10 (2004): 1641–61. https://ideas.repec.org//a/eee/wdevel/v32y2004i10p1641-1661.html.

USAID. "Evaluations and Research." *LandLinks* (blog). Accessed June 18, 2024. https://www.land-links.org/evaluations-and-research/.

World Bank Group, Niklas Buehren, Markus Goldstein, Robert Osei, Isaac Osei-Akoto, Christopher Udry, and Andrew Agyei-Holmes. "The Effects of Land Title Registration on Tenure Security Investment and the Allocation of Productive Resources Evidence from Ghana." *World Bank Group*, 2020. https://documents1.worldbank.org/curated/en/789321598973160923/pdf/The-Effects-of-Land-Title-Registration-on-Tenure-Security-Investment-and-the-Allocation-of-Productive-Resources-Evidence-from-Ghana.pdf.

Wren-Lewis, Liam, Luis Becerra-Valbuena, and Kenneth Houngbedji. "Formalizing Land Rights Can Reduce Forest Loss: Experimental Evidence from Benin | Science Advances." *Science Advances*, 2020. https://www.science.org/doi/10.1126/sciadv.abb6914.

Nutritional health

1. Alternative protocols for the management of acute malnutrition

Management of acute malnutrition[2] covers interventions that support the identification and treatment of severe acute malnutrition (SAM) and moderate acute malnutrition (MAM). The former typically involves ready-to-use therapeutic feeding (RUTF), a daily dose of lipid and micronutrient-fortified peanut paste delivered to children. These specialized foods are designed to address specific nutritional deficiencies and are meant to be consumed regularly. By targeting micronutrient deficiencies and enhancing overall health outcomes, the intervention aims to reduce the rate of child mortality and morbidity associated with acute malnutrition. SAM and MAM have typically been treated separately, using different feeding products and protocols (Maust et al. 2015). While effective, interventions to manage SAM tend to be costly and logistically challenging. There is **high potential evidence** that integrating approaches to treat SAM and MAM could amplify coverage and reduce costs to improve food and nutrition security. However, existing WHO guidelines are not aligned with this simplified approach. There is a lack of evidence on agricultural productivity, income, and climate resilience, likely because these are not typical outcomes for this category of interventions.

RUTF can be effective relative to alternative dietary approaches to manage acute malnutrition, but additional research is needed to optimize the implementation of these programs. A Cochrane Review of 15 randomized and quasi-randomized controlled trials concluded that RUTF likely improves recovery and increases the rate of weight gain in children with SAM (Schoonees et al., 2019). However, the review notes that additional research is needed to capture nuances from specific interventions and their implementation. Evidence from Sierra Leone indicates that complementing counseling services targeting children with MAM with RUTF improved short-term recovery and lowered the risk of deteriorating to SAM. However, recovery rates were suboptimal, and differences were not sustained over time. In Niger, providing children with RUTF reduced the decline in weight-for-height Z score and the incidence of wasting and severe wasting over 8 months (Isanaka et al., 2009).

Adoption: Simplified approaches that combine treatment for SAM and MAM could help increase coverage. Coverage remains an important challenge, as 75 percent of acutely malnourished children do not access care (Bailey et al., 2020). The division of SAM and MAM treatments may imply a logistical and humanitarian burden, particularly during humanitarian emergencies (Bailey et al., 2020). Evidence from Kenya and South Sudan shows that combined protocols can lead to similar recovery rates, length of stay, average daily weight gain, and mid-upper arm circumference (MUAC) gain (Bailey et al., 2020). Evidence from Sierra Leone also indicates that integrated management can be an effective alternative and increase coverage (Maust et al., 2015). In Burkina Faso, a simplified, combined protocol based on early detection through household screening using bracelets was also effectively implemented at scale (Daures et al., 2020).

2 According to the WHO, acute malnutrition happens in children under 5 years of age when they have low weight-for-height and weight-for-length scores (i.e., below 2 standard deviations below the median of the WHO child growth standards) or have nutritional edema (WHO, 2023).

Cost-effectiveness: Cost-effectiveness compares variation in therapeutic feeding delivery protocols, not therapeutic feeding, compared to other types of responses to acute malnutrition. Several studies have assessed the cost-effectiveness of changing the RUTF formulation using locally-sourced or alternative ingredients, with mixed results across different settings (Sierra Leone; Malawi; Malawi; Zambia; Bangladesh) (Hendrixson et al., 2020; Bahwere et al., 2014; Oakley et al., 2010; Irena et al., 2015; Hossain et al., 2020). These mainly target milk, which is the most costly component of RUTF. The simplified protocol tested in Kenya and South Sudan shows promise to lower costs, if implemented at scale (Bailey et al., 2020). The average number of sachets provided to children with SAM across the two countries declined from 193 to 122 under the simplified protocol. Taking costs and recovery rates into consideration, the simplified protocol costs US$123 less per child than the standard protocol.

Context: The effectiveness of acute malnutrition management can vary significantly with context. For one, implementation is heavily impacted by the quality of existing delivery channels, which can entail important challenges in fragile settings. In some settings, taste preferences may also affect the adoption of RUTF. In Cambodia, a locally-produced, fish-based RUTF achieved similar outcomes as the traditional formulation (Sigh et al., 2018). However, the reformulation of RUFT using alternative ingredients is not always as effective and should be considered carefully.

Bahwere, Paluku, Theresa Banda, Kate Sadler, Gertrude Nyirenda, Victor Owino, Bina Shaba, Filippo Dibari, and Steve Collins. "Effectiveness of Milk Whey Protein-Based Ready-to-Use Therapeutic Food in Treatment of Severe Acute Malnutrition in Malawian under-5 Children: A Randomised, Double-Blind, Controlled Non-Inferiority Clinical Trial." *Maternal & Child Nutrition* 10, no. 3 (July 2014): 436–51. https://doi.org/10.1111/mcn.12112.

Bailey, Jeanette, Charles Opondo, Natasha Lelijveld, Bethany Marron, Pamela Onyo, Eunice N. Musyoki, Susan W. Adongo, Mark Manary, André Briend, and Marko Kerac. "A Simplified, Combined Protocol versus Standard Treatment for Acute Malnutrition in Children 6–59 Months (ComPAS Trial): A Cluster-Randomized Controlled Non-Inferiority Trial in Kenya and South Sudan." Edited by James K. Tumwine. *PLOS Medicine* 17, no. 7 (July 9, 2020): e1003192. https://doi.org/10.1371/journal.pmed.1003192.

Daures, Maguy, Kevin Phelan, Mariama Issoufou, Séni Kouanda, Ousmane Sawadogo, Kader Issaley, Cecile Cazes, et al. "New Approach to Simplifying and Optimising Acute Malnutrition Treatment in Children Aged 6–59 Months: The OptiMA Single-Arm Proof-of-Concept Trial in Burkina Faso." *British Journal of Nutrition* 123, no. 7 (April 2020): 756–67. https://doi.org/10.1017/S0007114519003258.

Hendrixson, David Taylor, Claire Godbout, Alyssa Los, Meghan Callaghan-Gillespie, Melody Mui, Donna Wegner, Taylor Bryant, Aminata Koroma, and Mark J. Manary. "Treatment of Severe Acute Malnutrition with Oat or Standard Ready-to-Use Therapeutic Food: A Triple-Blind, Randomised Controlled Clinical Trial." *Gut* 69, no. 12 (December 2020): 2143–49. https://doi.org/10.1136/gutjnl-2020-320769.

Hossain, Md Iqbal, Sayeeda Huq, M. Munirul Islam, and Tahmeed Ahmed. "Acceptability and Efficacy of Ready-to-Use Therapeutic Food Using Soy Protein Isolate in under-5 Children Suffering from Severe Acute Malnutrition in Bangladesh: A Double-Blind Randomized Non-Inferiority Trial." E*uropean Journal of Nutrition* 59, no. 3 (April 2020): 1149–61. https://doi.org/10.1007/s00394-019-01975-w.

Irena, Abel H., Paluku Bahwere, Victor O. Owino, ElHadji I. Diop, Max O. Bachmann, Clara Mbwili-Muleya, Filippo Dibari, Kate Sadler, and Steve Collins. "Comparison of the Effectiveness of a Milk-Free Soy-Maize-Sorghum-Based Ready-to-Use Therapeutic Food to Standard Ready-to-Use Therapeutic Food with 25% Milk in Nutrition Management of Severely Acutely Malnourished Zambian Children: An Equivalence Non-Blinded Cluster Randomised Controlled Trial." *Maternal & Child Nutrition* 11 Suppl 4, no. Suppl 4 (December 2015): 105–19. https://doi.org/10.1111/mcn.12054.

Isanaka, Sheila, Nohelly Nombela, Ali Djibo, Marie Poupard, Dominique Van Beckhoven, Valérie Gaboulaud, Philippe J. Guerin, and Rebecca F. Grais. "Effect of Preventive Supplementation with Ready-to-Use-Therapeutic Food on the Nutritional Status, Mortality and Morbidity of Children 6 to 60 Months in Niger: A Cluster Randomized Trial." JAMA : *The Journal of the American Medical Association* 301, no. 3 (January 21, 2009): 277–85. https://doi.org/10.1001/jama.2008.1018.

Maust, Amanda, Aminata S Koroma, Caroline Abla, Nneka Molokwu, Kelsey N Ryan, Lauren Singh, and Mark J Manary. "Severe and Moderate Acute Malnutrition Can Be Successfully Managed with an Integrated Protocol in Sierra Leone." The Journal of Nutrition 145, no. 11 (November 2015): 2604–9. https://doi.org/10.3945/jn.115.214957.

Oakley, Eleanor, Jason Reinking, Heidi Sandige, Indi Trehan, Gregg Kennedy, Kenneth Maleta, and Mark Manary. "A Ready-to-Use Therapeutic Food Containing 10% Milk Is Less Effective than One with 25% Milk in the Treatment of Severely Malnourished Children." *The Journal of Nutrition* 140, no. 12 (December 2010): 2248–52. https://doi.org/10.3945/jn.110.123828.

Schoonees, Anel, Martani J Lombard, Alfred Musekiwa, Etienne Nel, and Jimmy Volmink. "Ready-to-Use

Therapeutic Food (RUTF) for Home-Based Nutritional Rehabilitation of Severe Acute Malnutrition in Children from Six Months to Five Years of Age." Edited by Cochrane Developmental, Psychosocial and Learning Problems Group. *Cochrane Database of Systematic Reviews* 2019, no. 5 (May 15, 2019). https://doi.org/10.1002/14651858.CD009000.pub3.

Sigh, Sanne, Nanna Roos, Chhoun Chamnan, Arnaud Laillou, Sophanneary Prak, and Frank T. Wieringa. "Effectiveness of a Locally Produced, Fish-Based Food Product on Weight Gain among Cambodian Children in the Treatment of Acute Malnutrition: A Randomized Controlled Trial." *Nutrients* 10, no. 7 (July 2018): 909. https://doi.org/10.3390/nu10070909.

WHO. "WHO Guideline on the Prevention and Management of Wasting and Nutritional Oedema (Acute Malnutrition) in Infants and Children under 5 Years," 2023. https://files.magicapp.org/guideline/1f7d1f1b-4ecb-4b92-873e-bdfab421a296/published_guideline_7352-1_2.pdf.

2. Community health workers (CHWs)

Community health workers (CHWs) are members of local communities who serve as liaisons between individuals and clinical care providers. They may go door-to-door visiting community members or serve as home health aides or local agents at a community center. While CHWs may not have the expertise to provide high-quality care, they can deliver information and basic care, distribute essential goods, connect members of the community to other medical services, and provide referrals to the formal health system as needed. In cases where CHWs do have the knowledge to provide quality care, they may not have the incentives or motivation to do so. Some programs aim to improve CHW's performance by changing the selection process, conducting performance monitoring, and offering financial incentives. There is **high potential evidence** on the impacts of CHWs on health status, but further research is needed on ways to fully harness the potential of CHWs and their impact on health outcomes, including nutrition-related outcomes. There is a lack of evidence on agricultural productivity, income, and climate resilience, likely because these are not typical outcomes for this category of interventions.

In Uganda, researchers evaluated an entrepreneurial model in which volunteer community members received a small profit per health product sold and a small incentive per household visit to pregnant women or infants (Nyqvist et al., 2019). Households served by the entrepreneurial community health promoter program saw improved health knowledge. In the case of nutrition, 63.8 percent of such households were aware of food with added vitamins or nutrients compared to 59.1 percent in villages with no CHW program (an 8 percent increase).

In low- and middle-income countries, providing performance-based pay in addition to base pay can also help improve healthcare provider performance on well-chosen indicators relative to providing only base pay. However, ensuring that the incentivized activities are within the health workers' direct control is an important consideration. CHWs are often incentivized based on performance and service utilization metrics, such as the number of children weighed to track malnutrition. Service utilization is often less directly in the control of the CHW or health service provider. In Rwanda, community health worker cooperatives were rewarded for utilization of five targeted maternal and child health services by their communities–growth monitoring of children, antenatal care, in-facility deliveries, and family planning consultations for new and regular users (Shapira et al., 2018). However, performance payment did not improve the monitoring of children for nutritional status or the other targeted outcomes. Additionally, it did not increase CHW effort or impact the operation of cooperatives. In India, researchers evaluated whether dividing incentives among workers in proportion to the measured gains in child health outcomes they contributed towards was more effective than prizes awarded solely to the top performer (Singh and Masters, 2020). Proportional incentives for Anganwadi workers reduced malnutrition by 4.3 percentage points at the time of the intervention and by 5.9 percentage points three months after the program ended relative to a "winner-take-all" prize. Gains were larger among lower-ranked workers.

Cost-effectiveness: Mixed. Highly cost-effective compared to care provided in health facilities. However, results depend on training, monitoring, and incentives, and the target interventions. A literature review on community health workers (CHWs) in health programs in lower- and middle-income countries suggests

that CHWs can be relatively cost-effective for tuberculosis, reproductive, maternal, newborn, and child health compared to the standard of care delivered by doctors and nurses (Vaughan et al., 2015). Early CHW programs were based on a volunteer model, but most programs have since moved away from this because many CHWs needed to pursue other income-earning activities that took away time from their CHW role. In place of the volunteer model, three other models have emerged: (1) the common model, which provides fixed wages; (2) the entrepreneurial model in which CHWs purchase health products wholesale to then sell to community members; and (3) the incentive model, which provides incentive pay based on performance, not entrepreneurship. A study in Uganda compared an entrepreneurial model in which CHWs sold treatment for child diarrhea and kept the profits to a more traditional CHW model in which CHWs distributed products for free (Wagner et al., 2020). In this case, the traditional model led to a 74 percent increase in CHW effort relative to the entrepreneurial model. CHWs in the entrepreneurial model did not want to ask their neighbors to purchase the products, while those in the traditional model felt good about giving products away for free and thereby helping their community.

Context: CHW selection is another important factor that can have downstream impacts on health outcomes. In Zambia, career-oriented recruitment improved the applicant pool and job performance of Community Health Assistants (CHAs) (Ashraf et al., 2020). CHAs in the career opportunities group significantly improved maternal and child health across a variety of health outcomes, including nutrition. In communities serviced by CHAs recruited with career incentives, the rate of child malnutrition was 25 percent lower compared to CHAs recruited with an emphasis on community service.

Rigorous research is also needed on the impact of digital/mHealth platforms for monitoring CHW performance, delivering CHW payment, and supporting CHW performance on health outcomes (Feroz et al., 2020). Monitoring health worker attendance and performance, including community monitoring interventions, may elicit greater effort in the short run, but there is mixed evidence that it works in the long term.

Ashraf, Nava, Oriana Bandiera, Edward Davenport, and Scott S. Lee. "Losing Prosociality in the Quest for Talent? Sorting, Selection, and Productivity in the Delivery of Public Services." *American Economic Review* 110, no. 5 (May 1, 2020): 1355–94. https://doi.org/10.1257/aer.20180326.

Björkman Nyqvist, Martina, Andrea Guariso, Jakob Svensson, and David Yanagizawa-Drott. "Reducing Child Mortality in the Last Mile: Experimental Evidence on Community Health Promoters in Uganda." *American Economic Journal: Applied Economics* 11, no. 3 (July 2019): 155–92. https://doi.org/10.1257/app.20170201.

Feroz, Anam, Rawshan Jabeen, and Sarah Saleem. "Using Mobile Phones to Improve Community Health Workers Performance in Low-and-Middle-Income Countries." *BMC Public Health* 20, no. 1 (January 13, 2020): 49. https://doi.org/10.1186/s12889-020-8173-3.

Shapira, Gil, Ina Kalisa, Jeanine Condo, James Humuza, Cathy Mugeni, Denis Nkunda, and Jeanette Walldorf. "Going beyond Incentivizing Formal Health Providers: Evidence from the Rwanda Community Performance-Based Financing Program." *Health Economics* 27, no. 12 (2018): 2087–2106. https://doi.org/10.1002/hec.3822.

Singh, Prakarsh, and William A. Masters. "Performance Bonuses in the Public Sector: Winner-Take-All Prizes versus Proportional Payments to Reduce Child Malnutrition in India." *Journal of Development Economics* 146 (September 2020): 102295. https://doi.org/10.1016/j.jdeveco.2018.10.003.

Vaughan, Kelsey, Maryse C. Kok, Sophie Witter, and Marjolein Dieleman. "Costs and Cost-Effectiveness of Community Health Workers: Evidence from a Literature Review." *Human Resources for Health* 13, no. 1 (September 1, 2015): 71. https://doi.org/10.1186/s12960-015-0070-y.

Wagner, Zachary, John Bosco Asiimwe, and David Levine. "When Financial Incentives Backfire: Evidence from a Community Health Worker Experiment in Uganda." *Journal of Development Economics* 144, no. C (2020). https://econpapers.repec.org/article/eeedeveco/v_3a144_3ay_3a2020_3ai_3ac_3as0304387819307801.htm.

3. Fortification

Fortification interventions involve adding micronutrients such as iron or iodine to food products such as salt and flour. These policies are widely implemented across lower and higher-income countries. Crop fortification seeks to improve the nutritional value of staple foods to address dietary deficiencies and enhance public health outcomes. By incorporating essential nutrients such as iron, zinc, and vitamin A into crops during growth, processing, or distribution, fortified foods offer a way to increase micronutrient intake and improve health and well-being within target communities. We reviewed crop fortification in an earlier section. This section focuses on the fortification of processed food products.

A systematic review of randomized and controlled trials of processed complementary foods fortified with a range of micronutrients is effective at preventing anemia in infants and young children but otherwise shows limited impacts (Csölle et al. 2022). A meta-analysis of rice fortified with iron and other micronutrients has an uncertain impact on reducing anemia in young children (Peña-Rosas et al. 2019). Despite evidence of direct impacts on anemia, there is **good evidence** of the impacts of fortification programs in lower-income countries on nutrition security. There is a lack of evidence on agricultural productivity, income, and climate resilience because they are not typically targeted outcomes for this category of interventions. Most evidence considers schools and markets as delivery mechanisms. Costs and benefits may differ in rural areas where there is low market access or when targets of micronutrients are young children who have not yet enrolled in school.

One study in Bihar, India, finds that distributing double-fortified salt via school means can reduce anemia, whereas another study from Bihar finds that neither subsidized sales nor the free distribution of double-fortified salt directly to households have detectable impacts on anemia (Krämer et al., 2021; Banerjee et al., 2018). Double-fortified salts distributed via schools had longer-run impacts on anemia in Bihar but no impact on cognitive outcomes (von Grafenstein et al., 2023). Community-level iron fortification of flour in India showed initial improvements in weakness (a symptom consistent with anemia), but the impact declined over time as take-up declined (Banerjee et al., 2011). Studies from China (1, 2) suggest changes in iodine regulations in China resulted in improved education outcomes but did not directly measure anthropometric outcomes (Deng and Lindeboom, 2022; Huang et al., 2020).

Adoption: Incentives for shopkeepers and "edutainment" films on the benefits of fortified salt can substantially increase usage (Banerjee et al., 2015).

Cost-effectiveness: Highly cost-effective, although less evidence is available in rural areas of low-income countries. Fortification is more likely to be highly cost-effective in urban areas where households purchase most food for consumption. In rural areas, it would depend on whether fortified products are regularly purchased (salt) or grown on household plots (maize flour, cassava flour). Evidence from China suggests that salt iodization is a highly cost-effective intervention to improve lifetime income via increases in school attendance. Evidence from Bihar suggests that distributing double-fortified salts at primary schools is highly cost-effective, with a cost of $280 per DALY (Krämer et al., 2021).

Context: Fortification is a promising approach in circumstances where rural households purchase processed grains, food, or salt from local markets. Subsistence producers who largely consume their home production may be less likely to benefit from fortification done at commercial facilities. Fortification also requires coordination among commercial food processors to ensure safe and high-quality standards. As such, it may be a more suitable intervention in urban areas than in rural settings, where biofortification and supplementation are alternative interventions. For example, biofortification has been found to be less cost-effective than supplementation and fortification in Latin America but potentially more cost-effective in sub-Saharan Africa and South Asia, which are significantly more rural regions (Meenakshi et al., 2010).

Assessment, US EPA National Center for Environmental. “Clinical Features of Patients Infected with 2019 Novel Coronavirus in Wuhan, China.” WEB SITE, March 15, 2009. https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/6766320.

Banerjee, Abhijit, Sharon Barnhardt, and Esther Duflo. “Can Iron-Fortified Salt Control Anemia? Evidence from Two Experiments in Rural Bihar,” n.d.

Banerjee, Abhijit, Sharon Barnhardt, and Esther Duflo. “Movies, Margins and Marketing: Encouraging the Adoption of Iron-Fortified Salt.” Cambridge, MA: National Bureau of Economic Research, October 2015. https://doi.org/10.3386/w21616.

Banerjee, Abhijit, Esther Duflo, and Rachel Glennerster. “Is Decentralized Iron Fortification a Feasible Option to Fight Anemia Among the Poorest?” In *Explorations in the Economics of Aging*, 317–44. University of Chicago Press, 2011. https://www.nber.org/books-and-chapters/explorations-economics-aging/decentralized-iron-fortification-feasible-option-fight-anemia-among-poorest.

Csölle, Ildikó, Regina Felső, Éva Szabó, Maria-Inti Metzendorf, Lukas Schwingshackl, Tamás Ferenci, and Szimonetta Lohner. “Health Outcomes Associated with Micronutrient-Fortified Complementary Foods in Infants and Young Children Aged 6–23 Months: A Systematic Review and Meta-Analysis.” *The Lancet Child & Adolescent Health* 6, no. 8 (August 1, 2022): 533–44. https://doi.org/10.1016/S2352-4642(22)00147-X.

Deng, Zichen, and Maarten Lindeboom. “A Bit of Salt, a Trace of Life: Gender Norms and the Impact of a Salt Iodization Program on Human Capital Formation of School Aged Children.” *Journal of Health Economics* 83 (May 1, 2022): 102614. https://doi.org/10.1016/j.jhealeco.2022.102614.

Grafenstein, Liza von, Abhijeet Kumar, Santosh Kumar, and Sebastian Vollmer. “Medium-Run Impacts of Iron-Fortified School Lunch on Anaemia, Cognition, and Learning Outcomes in India*.” *Oxford Bulletin of Economics and Statistics* 85, no. 6 (2023): 1262–94. https://doi.org/10.1111/obes.12559.

Krämer, Marion, Santosh Kumar, and Sebastian Vollmer. “Improving Child Health and Cognition: Evidence from a School-Based Nutrition Intervention in India.” *The Review of Economics and Statistics* 103, no. 5 (November 30, 2021): 818–34. https://doi.org/10.1162/rest_a_00950.

Meenakshi, J. V., Nancy L. Johnson, Victor M. Manyong, Hugo DeGroote, Josyline Javelosa, David R. Yanggen, Firdousi Naher, Carolina Gonzalez, James García, and Erika Meng. “How Cost-Effective Is Biofortification in Combating Micronutrient Malnutrition? An Ex Ante Assessment.” *World Development* 38, no. 1 (2010): 64–75. https://econpapers.repec.org/article/eeewdevel/v_3a38_3ay_3a2010_3ai_3a1_3ap_3a64-75.htm.

Peña-Rosas, Juan Pablo, Prasanna Mithra, Bhaskaran Unnikrishnan, Nithin Kumar, Luz Maria De-Regil, N. Sreekumaran Nair, Maria N. Garcia-Casal, and Juan Antonio Solon. “Fortification of Rice with Vitamins and Minerals for Addressing Micronutrient Malnutrition.” *The Cochrane Database of Systematic Reviews* 2019, no. 10 (October 25, 2019): CD009902. https://doi.org/10.1002/14651858.CD009902.pub2.

4. Improved infant and young child feeding (IYCF) practices

Improved Infant and Young Child Feeding (IYCF) practices are defined as interventions that are based on WHO guidelines to improve feeding practices of children under two years of age. Many IYCF interventions are centered on the adoption of exclusive breastfeeding practices, while others include nutrition education programs and the provision of calorie-dense complementary foods (complementary foods designed to reduce acute malnutrition are reviewed in the intervention category 'Management of acute malnutrition.' We note that it is not always possible to distinguish between these two intervention categories). The initiatives aim to improve infant survival rates and address nutritional deficiencies resulting from inadequate feeding practices by advocating for feeding methods that emphasize the importance of breastfeeding and providing information about how to introduce nutrient-rich solid foods into a baby's diet. There is **good evidence** supporting improved infant and young child feeding practice interventions on food and nutrition security. There is no evidence of agricultural productivity, income, or climate resilience because these outcomes are not typically target outcomes for this category of intervention. The bulk of evidence for the cost-effectiveness of IYCF practices is centered on assessing the financial impact of not breastfeeding. Globally, the cost of not breastfeeding amounts to a staggering US$1.1 billion in health system treatment costs each year (Walters et al., 2019).

The availability of formula, particularly in households with poor-quality water, increases infant mortality, underscoring the importance of promoting breastfeeding (Anttila-Hughes et al., 2018). Evidence from Latin America suggests that exclusive breastfeeding for infants aged 0-3 months and partial breastfeeding throughout infancy could prevent a significant percentage of infant deaths from diseases (Betran et al., 2001). However, there remains a concerning gender disparity in breastfeeding rates, as observed in India (Jayachandran and Kuziemko, 2011). Okonogi et al. demonstrate that introducing complementary foods such as Koko-plus into the market increases children's weight, but its impact varies based on access to safe drinking water, and it does not affect height (Okonogi et al., 2021). There is suggestive evidence that IYCF practices that involve nutritional education could have positive effects on mothers' nutrition and empowerment outcomes, which could translate into better child health and nutrition outcomes. HKI's E-HFP program had significant positive effects on agricultural outcomes, increasing mothers' fruit/meat/poultry intake and dietary diversity (Olney et al., 2015). The prevalence of underweight was significantly reduced among mothers in treatment villages, and the E-HFP program also positively affected mothers' overall empowerment score, purchasing decisions, and healthcare decisions, indicating that these positive impacts may also improve the mothers' ability to care for their children (Olney et al., 2015).

Adoption: Several implementation challenges may arise in settings where ICYF practices are recommended, including health system constraints, economic barriers, and lack of coordination or integration in conflict zones. Uptake of breastfeeding practices or complementary foods may be low among households and communities due to cultural norms or other factors.

Cost-effectiveness: Likely high. Campaigns for young child feeding practices related to introducing food need to be tailored to local contexts, which raises fixed implementation costs. Campaigns to promote breastfeeding would not require as much local tailoring. Once curricula are developed, there would be a

relatively low marginal cost of adding additional households. More research is needed on delivery media (in-person v digital, groups v individual, number of classes, etc). High returns to improving childhood nutrition. A cost analysis by Walters et al shows that economic losses due to premature child and women's mortality reach US$53.7 billion annually, with cognitive losses comprising the largest component at US$285.4 billion per year (Walters et al., 2019). Countries with low exclusive breastfeeding rates face economic losses exceeding 0.5 percent of their GNI (Walters et al., 2019). Additional experimental evidence from Walters et al suggests that investing in a national breastfeeding promotion strategy in Vietnam could prevent 200 child deaths annually and yield a remarkable monetary benefit of US$2.39 for every US$1 invested, resulting in a 139 percent return on investment (Walters et al., 2016). This highlights the significant cost-effectiveness and global importance of prioritizing breastfeeding initiatives.

Context: Adoption of ICYF practices may be most suitable in contexts where the risk of malnutrition for children under two years of age is high (climate and food insecure regions, conflict zones, etc.). Challenges may occur if the implementing environment lacks supportive policies or workforce capacity or if cultural or religious barriers result in low adoption of recommended interventions.

Anttila-Hughes, Jesse K., Lia C.H. Fernald, Paul J. Gertler, Patrick Krause, Eleanor Tsai, and Bruce Wydick. "Mortality from Nestlé's Marketing of Infant Formula in Low and Middle-Income Countries." Working Paper. Working Paper Series. National Bureau of Economic Research, March 2018. https://doi.org/10.3386/w24452.

Betrán, Ana P., Mercedes de Onís, Jeremy A. Lauer, and José Villar. "Ecological Study of Effect of Breast Feeding on Infant Mortality in Latin America." BMJ 323, no. 7308 (August 11, 2001): 303. https://doi.org/10.1136/bmj.323.7308.303.

Jayachandran, Seema, and Ilyana Kuziemko. "Why Do Mothers Breastfeed Girls Less than Boys? Evidence and Implications for Child Health in India*." The Quarterly Journal of Economics 126, no. 3 (August 1, 2011): 1485–1538. https://doi.org/10.1093/qje/qjr029.

Okonogi, Satoru, Reginald Annan, and Takeshi Sakurai. "Improving Infant Nutrition through the Market: Experimental Evidence in Ghana." SSRN Scholarly Paper. Rochester, NY, July 8, 2021. https://doi.org/10.2139/ssrn.3771891.

Olney, Deanna K., Abdoulaye Pedehombga, Marie T. Ruel, and Andrew Dillon. "A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso Reduces Anemia, Wasting, and Diarrhea in Children 3-12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial." Journal of Nutrition 145, no. 6 (2015): 1317–24. https://doi.org/10.3945/jn.114.203539.

Walters, Dylan D, Linh T H Phan, and Roger Mathisen. "The Cost of Not Breastfeeding: Global Results from a New Tool." Health Policy and Planning 34, no. 6 (July 1, 2019): 407–17. https://doi.org/10.1093/heapol/czz050.

5. Supplementation

Mass supplementation interventions involve the direct distribution of supplements to address micronutrient deficiencies (in contrast to fortification interventions). In lower-income settings, adults, pregnant women, and children commonly experience nutrient deficiencies and low energy levels. A supplementation intervention addresses this by providing regular consumption of nutritional supplements that target specific micronutrient deficiencies. By improving overall health outcomes and energy levels, the intervention aims to enhance the quality of life, productivity, wages, and life outcomes for individuals in these settings. There is **low evidence** of the impacts of supplementation programs in lower-income countries on food and nutrition security. There is some evidence that they improve nutrition outcomes, but there were relatively few high-quality studies. There is a lack of evidence on agricultural productivity, income, and climate resilience, likely because these are not typical outcomes for this category of interventions.

A systematic review of iron supplementation suggests improvements in anemia but raises concerns about adverse side effects on growth and health outcomes (Pasricha et al., 2013). Short-run evidence on iron supplementation in Peru suggests significant cognitive improvements among anemic children, resulting in improved academic performance and grade promotion (Chong et al., 2016). Nutritional supplementation of pregnant women and subsequent supplementation of their children before two years of age in Pakistan improves children's development and reduces the risk of stunting (Soofi et al., 2022).

Long-run evidence from early randomized trials of protein supplementation in Guatemala [1,2] and Panama suggests early childhood supplementation improves adult schooling and wages (Calderón et al., 2008; Hoddinott et al., 2008). Iodine supplementation in Tanzania may also improve long-run education and wages, but access to this program was not randomized (Araújo et al., 2021).

Adoption: Promotional videos can improve supplementation uptake when iron pills are distributed through local village health clinics (Chong et al., 2016).

Cost-effectiveness: Unclear, likely high. Inexpensive to deliver supplements at scale to school children, but costs would be higher if the goal is to reach younger children who are not yet attending school. Promotional videos are a cost-effective way to improve the effectiveness of clinic-centered supplementation programs, reducing the cost per case of anemia avoided by over 90 percent compared to commonly implemented "Weekly Iron and Folic Acid Supplementation" programs, which deliver supplements to households (Chong et al., 2016).

Araujo, Daniel, Bladimir Carrillo, and Breno Sampaio. *The Long-Run Economic Consequences of Iodine Supplementation*, 2021.

Behrman, Jere R, Maria C Calderon, Samuel H Preston, John Hoddinott, Reynaldo Martorell, and Aryeh D Stein. "Nutritional Supplementation in Girls Influences the Growth of Their Children: Prospective Study in Guatemala1234." *The American Journal of Clinical Nutrition* 90, no. 5 (November 2009): 1372–79. https://doi.org/10.3945/ajcn.2009.27524.

Calderón, María Cecilia. "High Quality Nutrition in Childhood, Body Size and Wages in Early Adulthood: Evidence from Guatemalan Workers." *Económica* 54 (December 30, 2008): 41–86. https://revistas.unlp.edu.ar/Economica/article/view/5490.

Chong, Alberto, Isabelle Cohen, Erica Field, Eduardo Nakasone, and Maximo Torero. "Iron Deficiency and Schooling Attainment in Peru." *American Economic Journal: Applied Economics* 8, no. 4 (October 2016): 222–55. https://doi.org/10.1257/app.20140494.

Hoddinott, John, and Lucy Bassett. "Conditional Cash Transfer Programs and Nutrition in Latin America: Assessment of Impacts and Strategies for Improvement." *SSRN Electronic Journal*, 2008. https://doi.org/10.2139/ssrn.1305326.

Hoddinott, John, John A. Maluccio, Jere R. Behrman, Rafael Flores, and Reynaldo Martorell. "Effect of a Nutrition Intervention during Early Childhood on Economic Productivity in Guatemalan Adults." *Lancet (London, England)* 371, no. 9610 (February 2, 2008): 411–16. https://doi.org/10.1016/S0140-6736(08)60205-6.

Pasricha, Sant-Rayn, Emily Hayes, Kongolo Kalumba, and Beverley-Ann Biggs. "Effect of Daily Iron Supplementation on Health in Children Aged 4–23 Months: A Systematic Review and Meta-Analysis of Randomised Controlled Trials." *The Lancet Global Health* 1, no. 2 (August 1, 2013): e77–86. https://doi.org/10.1016/S2214-109X(13)70046-9.

Soofi, Sajid Bashir, Gul Nawaz Khan, Shabina Ariff, Yasir Ihtesham, Mahamadou Tanimoune, Arjumand Rizvi, Muhammad Sajid, Cecilia Garzon, Saskia de Pee, and Zulfiqar A. Bhutta. "Effectiveness of Nutritional Supplementation during the First 1000-Days of Life to Reduce Child Undernutrition: A Cluster Randomized Controlled Trial in Pakistan." *The Lancet Regional Health - Southeast Asia* 4 (September 1, 2022). https://doi.org/10.1016/j.lansea.2022.100035.

6. School feeding

School feeding programs provide meals in school for children and are widespread in high-income countries and increasingly in lower-income countries as well (Gelli and Daryanani, 2013). The goal of school feeding programs is to enhance the educational outcomes of children by ensuring that children receive nutritional meals during school time, thereby improving their performance. In theory, by providing a nutrient-rich meal, school feeding could improve nutrition security for school-aged children, which is the main target outcome of this review. There is **mixed evidence** of the impacts of school feeding programs on nutrition security. There is a lack of evidence related to agricultural productivity, household incomes, or climate resilience, but these are not typically target outcomes for school feeding programs.

In Ghana, India, and Kenya, school feeding improved measures of nutritional health like height-for-age and weight-for-age, particularly for girls and younger children living in poorer regions of Ghana and for only boys in Kenya (Aulo et al., 2019; Singh et al., 2014; Kremer & Vermeersch et al., 2005). Two studies from India (1,2) also showed that school feeding programs significantly reduced anemia and improved hemoglobin levels in children. In contrast, a school feeding program in the Lao People's Democratic Republic (Lao PDR) improved neither height-for-age nor weight-for-age in school children - though this may have been due to implementation challenges (Buttenheim, 2011). In Ghana, a "Home Grown" school feeding program that integrated local smallholder farmers did not affect local farms or overall household income (Gelli et al., 2021).

Most research examines the relationship between school feeding programs and educational outcomes, such as attendance and school performance. Although not comprehensively studied in this review, we note several studies that address these outcomes because they may be complementary to direct nutrition outcomes. School feeding programs encourage attendance because children are guaranteed to have a nutritious meal provided by the school. In Burkina Faso, Ghana, and Kenya, school feeding programs increased school attendance (Kazianga et al., 2012; Aurino et al., 2018; Vermeersch and Kremer, 2005). A comprehensive review recently published by the Global Education Evidence Advisory Panel (GEEAP) suggests that school feeding programs are effective but relatively expensive at improving education outcomes (GEEAP, 2023).

Adoption: Political and logistical constraints can limit the effective adoption and sustained operation of school feeding programs, including "Home Grown" programs as in Ghana and more standard school feeding programs in Lao PDR (Gelli et al., 2021; Buttenheim, 2011).

Cost-effectiveness: Mixed evidence on cost-effectiveness for nutrition. A review, including data on the costs of school feeding from 74 countries, including 12 high-income, 40 middle-income, and 22 low-income countries, found that such programs cost an average of $54 per student per year in low-income countries (Gelli and Daryanani, 2013). However, none of these cost-effectiveness studies have compared school feeding programs to other interventions designed to improve nutrition. The total budget for school feeding in low-income countries was found to be, on average, 68 percent of the estimated total primary school education budget. School feeding investments that are targeted to reach only a portion of primary school children can lower total costs. As countries get richer, school feeding costs become a much smaller proportion

of education costs (Gelli and Daryanani, 2013). A school feeding program administered by WFP in Burkina Faso cost $41 per student per year, and a school feeding program administered by the Government of Ghana costs $66 per student per year (Kaziranga et al., 2012; Aurino et al., 2018).

In India, a school feeding program that provided double-fortified salt as part of the midday meal program was associated with one DALY averted, costing approximately US$280. The World Health Organization assesses interventions as very cost-effective if the cost per DALY averted is less than the GNI per capita of the country where the intervention is going to be implemented. India's GNI per capita at purchasing power parity in 2015 was US$6,030, which indicates that the intervention was extremely cost-effective in terms of cost incurred per DALY averted (Kramer et al., 2013). School feeding programs are an opportunity to provide a standardized meal with specific nutrition requirements to many children at once. As a result, they may be a more cost-effective option to deliver fortified foods (such as salt) than programs that target individual households.

Context: Broader school programs, as implemented in Burkina Faso and Ghana, may be more effective at impacting school attendance than narrower nutritional interventions like introducing fortified salt in India (Kazianga et al., 2012; Aurino et al., 2018; Krämer et al., 2021). Evidence from India also indicates that, in certain contexts, improving the monitoring of existing programs can be more effective at improving child health than introducing a new program (Berry et al., 2021). A school feeding program in India was especially effective as a safety net during adverse conditions like drought (Singh et. al., 2014).

Aurino, Elisabetta, Aulo Gelli, Clement Adamba, Isaac Osei-Akoto, and Harold Alderman. "Food for Thought? Experimental Evidence on the Learning Impacts of a Large-Scale School Feeding Program in Ghana," n.d.

Berry, James, Saurabh Mehta, Priya Mukherjee, Hannah Ruebeck, and Gauri Kartini Shastry. "Crowd-out in School-Based Health Interventions: Evidence from India's Midday Meals Program." *Journal of Public Economics* 204, no. C (2021). https://ideas.repec.org//a/eee/pubeco/v204y2021ics0047272721001882.html.

Buttenheim, Alison, Alderman, and Jed Friedman. "Impact Evaluation of School Feeding Programmes in Lao People's Democratic Republic." *Journal of Development Effectiveness*, 2011. https://www.tandfonline.com/doi/full/10.1080/19439342.2011.634511.

GEEAP. "2023 Cost-Effective Approaches to Improve Global Learning," 2023. https://thedocs.worldbank.org/en/doc/231d98251cf326922518be0cbe306fdc-0200022023/related/GEEAP-Report-Smart-Buys-2023-final.pdf.

Gelli, Aulo, and Roshan Daryanani. "Are School Feeding Programs in Low-Income Settings Sustainable? Insights on the Costs of School Feeding Compared with Investments in Primary Education - Aulo Gelli, Roshan Daryanani, 2013." *Food and Nutrition Bulletin*, 2013. https://journals.sagepub.com/doi/abs/10.1177/156482651303400303.

Gelli, Aulo, Amy Margolies, Marco Santacroce, Natalie Roschnik, and Aisha Twalibu. "Using a Community-Based Early Childhood Development Center as a Platform to Promote Production and Consumption Diversity Increases Children's Dietary Intake and Reduces Stunting in Malawi- A Cluster-Randomized Trial," 2018. https://drive.google.com/file/d/1F8-JkZOAqI-wh2YMTzsJEzreLWEF-u6i/view?usp=sharing.

Gelli, Aulo, Edoardo Masset, and Clement Adamba. "School Meals as a Market for Smallholder Agriculture." *IFPRI*, 2021.

Kazianga, Harounan, Damien de Walque, and Harold Alderman. "Educational and Child Labour Impacts of Two Food-for-Education Schemes: Evidence from a Randomised Trial in Rural Burkina Faso†." *Journal of African Economies* 21, no. 5 (November 1, 2012): 723–60. https://doi.org/10.1093/jae/ejs010.

———. "School Feeding Programs, Intrahousehold Allocation and the Nutrition of Siblings: Evidence from a Randomized Trial in Rural Burkina Faso." *Journal of Development Economics* 106, no. C (2014): 15–34. https://ideas.repec.org//a/eee/deveco/v106y2014icp15-34.html.

Krämer, Marion, Santosh Kumar, and Sebastian Vollmer. "Improving Child Health and Cognition: Evidence from a School-Based Nutrition Intervention in India." SSRN Scholarly Paper. Rochester, NY, June 1, 2018. https://doi.org/10.2139/ssrn.3389343.

Singh, Abhijeet, Albert Park, and Stefan Dercon. "School Meals as a Safety Net: An Evaluation of the Midday Meal Scheme in India | Economic Development and Cultural Change: Vol 62, No 2," 2013. https://www.journals.uchicago.edu/doi/10.1086/674097.

Vermeersch, Christel, and Michael Kremer. "School Meals, Educational Achievement, and School Competition: Evidence from a Randomized Evaluation." SSRN Scholarly Paper. Rochester, NY, November 1, 2004. https://doi.org/10.2139/ssrn.667881.

7. Home gardens

Programs promoting home gardens or Homestead Food Production (HFP) aim to increase dietary diversity and reduce malnutrition by increasing the amount of vegetables produced and consumed at the household level. Typically, the programs provide information and/or inputs for households to grow nutrient-dense crops in home gardens to improve access to and availability of vegetables (Blakstad et al., 2021). Overall, there is **low evidence** on the impacts of home garden programs on food and nutrition security, agricultural productivity, income, and climate resilience.

Several studies on a program in Bangladesh and a similar program in Cambodia report significant and lasting gains in vegetable production, dietary diversity, and adoption of best gardening practices (Baliki et al., 2019; Schreinemachers et al., 2016; Baliki et al., 2020; Depenbusch et al., 2022). Similarly, a home gardening program in Tanzania increased dietary diversity among treatment households (Blakstad et al., 2021). Another study in Nepal found that combining school gardens with home garden support led to a 15 percent increase in home garden productivity and a 26 percent increase in the food and nutrition knowledge of caregivers. Simultaneously, it also led to a 6 percent increase in the adoption of healthy food practices and consumption of vegetables among children, indicating that the program played an important role in nudging children toward healthier food choices (Schreinemachers et al., 2020).

The underlying causal mechanism is not always increased home garden production. For example, in Burkina Faso, an integrated HFP and nutrition information program provided seeds and drip irrigation to increase household production, as well as nutrition information. The program reduced consumption nutrient gaps in treatment households and led to improvements in anemia, wasting, and diarrhea, but the impacts were driven by different consumer choices rather than increases in household vegetable production, suggesting that home gardens help people learn about nutrition (Dillon et al., 2019; Olney et al., 2015).

Some studies provide inconclusive or null results. In Nepal, a combined home garden, poultry, and nutrition education program improved anemia and weight among target groups, though food security increased in both treatment and comparison groups (Osei et al., 2017). An HFP program in Kenya, Tanzania, and Uganda, which provided diet information, vegetable seeds, and training, found no significant impacts on vegetable production in Kenya and Uganda and no significant impacts on vegetable consumption in any setting (Depenbusch et al., 2021).

Cost-effectiveness: Unclear, likely mixed cost effectiveness depending on compliance and program design. Programs are not sufficiently disaggregated to attribute casual effects to home gardens. One study demonstrated that a home garden intervention in Bangladesh met WHO standards for cost-effectiveness in addressing nutrient deficiencies, particularly when scaled up (Schreinemachers et al., 2016). However, more evidence and analyses on cost-effectiveness are needed.

Context: The effectiveness of these programs may depend on targeting areas where families have available and underutilized land for vegetable production. In the three-country trial, household vegetable production only increased in Tanzania, where fewer households grew vegetables at baseline, while most households in Kenya and Uganda already grew vegetables before the intervention (Depenbusch et al., 2021).

Baliki, Ghassan, Tilman Brück, and Pepijn Schreinemachers. "Long-Term Behavioural Impact of an Integrated Home Garden Intervention- Evidence from Bangladesh." *Food Security*, 2019. https://drive.google.com/file/d/1bpJD7Xw0pzYlEBK3UtiIhhbsJ8irCTn2/view?usp=embed_facebook.

Baliki, Ghassan, Pepijn Schreinemachers, Tilman Brück, and Md. Nasir Uddin. "Impacts of Home Garden Intervention in Bangladesh after One, Three and Six Years." *Agriculture and Food Security*, 2022. https://drive.google.com/file/d/1l7w9bUDYN02DGFcTcgYPiJOifqbVHHeb/view?usp=embed_facebook.

Blakstad, Mia M., Dominic Mosha, Alexandra L. Bellows, Chelsey R. Canavan, Jarvis T. Chen, Killian Mlalama, Ramadhani A. Noor, Joyce Kinabo, Honorati Masanja, and Wafaie W. Fawzi. "Home Gardening Improves Dietary Diversity, a Cluster-Randomized Controlled Trial among Tanzanian Women." *Maternal & Child Nutrition* 17, no. 2 (April 2021): e13096. https://doi.org/10.1111/mcn.13096.

Depenbusch, Lutz, Pepijn Schreinemachers, Stuart Brown, and Ralph Roothaert. "Impact and Distributional Effects of a Home Garden and Nutrition Intervention in Cambodia." *Food Security* 14, no. 4 (August 1, 2022): 865–81. https://doi.org/10.1007/s12571-021-01235-y.

Dillon, Andrew, Joanne Arsenault, and Deanna Olney. "Nutrient Production and Micronutrient Gaps: Evidence from an Agriculture-Nutrition Randomized Control Trial." *American Journal of Agricultural Economics* 101, no. 3 (2019): 732–52. https://doi.org/10.1093/ajae/aay067.

Olney, Deanna K, Abdoulaye Pedehombga, Marie T Ruel, and Andrew Dillon. "A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso Reduces Anemia, Wasting, and Diarrhea in Children 3–12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial1, 2, 3." *The Journal of Nutrition* 145, no. 6 (June 1, 2015): 1317–24. https://doi.org/10.3945/jn.114.203539.

Osei, Akoto, Pooja Pandey, Jennifer Nielsen, Alissa Pries, David Spiro, Dale Davis, Victoria Quinn, and Nancy Haselow. "Combining Home Garden, Poultry, and Nutrition Education Program Targeted to Families With Young Children Improved Anemia Among Children and Anemia and Underweight Among Nonpregnant Women in Nepal." *Food and Nutrition Bulletin* 38, no. 1 (March 2017): 49–64. https://doi.org/10.1177/0379572116676427.

Schreinemachers, Pepijn, Marie Antoinette Patalagsa, and Nasir Uddin. "Impact and Cost-Effectiveness of Women's Training in Home Gardening and Nutrition in Bangladesh." *Journal of Development Effectiveness* 8, no. 4 (October 2016): 473–88. https://doi.org/10.1080/19439342.2016.1231704.

Schreinemachers, Pepijn, Ghassan Baliki, Rachana Manandhar Shrestha, Dhruba Raj Bhattarai, Ishwori P. Gautam, Puspa Lal Ghimire, Bhishma P. Subedi, and Tilman Brück. "Nudging children toward healthier food choices: an experiment combining school and home gardens." Global Food Security 26 (2020): 100454.

Behavior change communication

1. Nutrition campaigns

Nutrition education campaigns aim to improve the health status of households, particularly children and women, by increasing knowledge about foods that improve nutrition and overall health. These interventions address the lack of knowledge among adults and caregivers regarding daily dietary needs and micronutrient deficiencies in women of childbearing age and children. The goal is to enhance dietary diversity and improve anthropometric measures in children that are associated with improved well-being in adulthood. There is **good evidence** of the impacts of nutrition campaigns on nutrition outcomes. There is a lack of evidence on overall agricultural productivity, income, and climate resilience, likely because most programs focused on nutrition outcomes even when programs involved agricultural training components.

Behavior change campaigns have had a positive effect on dietary diversity in Kenya, Ethiopia, Tanzania, China, Burkina Faso, and Malawi (Boedecker et al., 2019; Kang et al., 2017; Kulwa et al., 2023; Shi et al., 2010; Dillon et al., 2019; Kuchenbecker et al., 2017). There is also evidence that nutrition campaigns improve anthropometric measures in children; programs in Ethiopia, China, and India reduce stunting and improve growth, and programs in Vietnam and Malawi report reductions in stunting and underweight for younger but not older children (Kang et al., 2017; Zhang et al., 2013; Vazir et al., 2013; Schroeder et al., 2002). A 3ie systematic review found that nutrition education programs generally have a positive impact on height, weight, and lower morbidity for young children and that programs with more intensive interventions (programs that include home visits, multiple meetings with peers and community leaders, or cooking demonstrations) have more robust results compared to lighter touch information awareness campaigns (Majamanda et al., 2014).

A project in Kenya focused on participatory approaches to promote nutrition education and production showed positive effects on the dietary diversity of young children using a matched differences-in-differences methodology (Boedecker et al. 2019). Several successful interventions developed their curriculum using participatory approaches that were attentive to food traditions and how women learn from other women (Kenya, Ethiopia, Burkina Faso) (Boedecker et al., 2019; Kang et al., 2017; Dillon et al., 2019). Programs in Ecuador, Ethiopia, and Vietnam used a positive deviance approach where researchers identify children with better health status compared to peers in households with similar wealth levels and develop a curriculum to share practices across families (Roche et al., 2017; Kang et al., 2017; Schroeder et al., 2002).

In many cases, behavior change campaigns are coupled with agricultural interventions so that participants are trained and provided inputs or other resources to grow nutrient-rich crops, as in Burkina Faso, Malawi (1, 2), Kenya (Olney et al., 2015; Kuchenbecker et al., 2017; Boedecker et al., 2019). Other nutrition education programs include cooking demonstrations (Tanzania) or information on complementary feeding (India 1, 2, Bangladesh, and China), which are covered in other review sections (Nita et al., 2004; Kulwa et al., 2023; Kilaru et al., 2005; Roy et al., 2005; Shi et al., 2010).

To be successful, nutrition campaigns must provide information that closes a knowledge gap and promotes actionable behavior change. For example, a behavior change campaign may help households learn about the importance of eating leafy vegetables among young children, and leafy vegetables are readily attainable or can be cultivated locally. A program in Kenya that promoted the production and consumption of leafy greens posited that changes in market prices for leafy greens may have contributed to an ambiguous effect on dietary diversity; their RCT design had high attrition and low power (Merchant et al., 2023).

Cost-effectiveness: There appear to be high returns to improving childhood nutrition. Once nutrition curricula are developed, there would be relatively low marginal cost of adding additional households. But nutrition campaigns often bundle numerous services (cooking classes, peer groups, household visits, etc.) and it was not possible to untangle which features were beneficial to evaluate cost-effectiveness.

They also need to be tailored to local contexts, which raises fixed costs. More research is needed on delivery media (in-person v digital, groups v individual, number of classes, etc). There is wide variation in the length, frequency, and intensity of nutrition education programs, and few studies reported information on cost-effectiveness. One exception was a study in Bangladesh, where the authors computed the cost of preventing malnutrition was between $18-37 USD per child (Roy et al., 2007). The 3ie systematic review found that working with local leaders and peer educators is as effective as experts and medical professionals, which can allow programs to save costs and promote strategies where nutrition education materials are tailored to the local context (Majamanda et al., 2014).

Context: Nutrition education campaigns have promising effects on improving childhood nutrition. Locally adapted campaigns with a bundle of interventions have the strongest effects. There is not enough evidence to assess which features of interventions have the highest returns. Nutrition campaigns are appropriate in settings where participants would be receptive to participating in multiple weeks of training, classes, or other touch points where families are capable of incorporating nutrition advice into their diets using foods that are affordable and available.

Bhandari, Nita, Sarmila Mazumder, Maharaj K. Bhan, Rajiv Bahl, Jose Martines, and Robert E. Black. "An Educational Intervention to Promote Appropriate Complementary Feeding Practices and Physical Growth in Infants and Young Children in Rural Haryana, India." *The Journal of Nutrition* 134, no. 9 (September 1, 2004): 2342–48. https://doi.org/10.1093/jn/134.9.2342.

Boedecker, Julia, Francis Odhiambo Odour, Carl Lachat, Patrick Van Damme, Gina Kennedy, and Céline Termote. "Participatory Farm Diversification and Nutrition Education Increase Dietary Diversity in Western Kenya." *Maternal & Child Nutrition* 15, no. 3 (2019): e12803. https://doi.org/10.1111/mcn.12803.

Dillon, Andrew, Joanne Arsenault, and Deanna Olney. "Nutrient Production and Micronutrient Gaps: Evidence from an Agriculture-Nutrition Randomized Control Trial." *American Journal of Agricultural Economics* 101, no. 3 (2019): 732–52. https://doi.org/10.1093/ajae/aay067.

Gelli, Aulo, Amy Margolies, Marco Santacroce, Natalie Roschnik, Aisha Twalibu, Mangani Katundu, Helen Moestue, Harold Alderman, and Marie Ruel. "Using a Community-Based Early Childhood Development Center as a Platform to Promote Production and Consumption Diversity Increases Children's Dietary Intake and Reduces Stunting in Malawi: A Cluster-Randomized Trial." *The Journal of Nutrition* 148, no. 10 (October 1, 2018): 1587–97. https://doi.org/10.1093/jn/nxy148.

Kang, Yunhee, Sungtae Kim, Sisay Sinamo, and Parul Christian. "Effectiveness of a Community-Based Nutrition Programme to Improve Child Growth in Rural Ethiopia: A Cluster Randomized Trial." *Maternal & Child Nutrition* 13, no. 1 (2017). https://doi.org/10.1111/mcn.12349.

Kang, Yunhee, Youn Kyoung Suh, Lemma Debele, Hee-Soon Juon, and Parul Christian. "Effects of a Community-Based Nutrition Promotion Programme on Child Feeding and Hygiene Practices among Caregivers in Rural Eastern Ethiopia." *Public Health Nutrition* 20, no. 8 (June 2017): 1461–72. https://doi.org/10.1017/S1368980016003347.

Kilaru, A, Paula L. Griffiths, S Ganapathy, and Shanti Ghosh. "Community-Based Nutrition Education for Improving Infant Growth in Rural Karnataka." *Indian Pediatrics*, 2005. https://www.indianpediatrics.net/may2005/425.pdf.

Kuchenbecker, Judith, Anika Reinbott, Beatrice Mtimuni, Michael B. Krawinkel, and Irmgard Jordan. "Nutrition Education Improves Dietary Diversity of Children 6-23 Months at Community-Level: Results from a Cluster Randomized Controlled Trial in Malawi." *PLOS ONE* 12, no. 4 (April 20, 2017): e0175216. https://doi.org/10.1371/journal.pone.0175216.

Kulwa, Kissa B. M., Peter S. Mamiro, and Patrick W. Kolsteren. "Nutrition Education Package Focusing on Infant and Young Child Feeding in Tanzania." *Journal of Nutrition Education and Behavior* 55, no. 7 (July 1, 2023): 493–508. https://doi.org/10.1016/j.jneb.2023.04.002.

Majamanda, J, D Maureen, T M Munkhondia, and J Carrier. "The Effectiveness of Community-Based Nutrition Education on the Nutrition Status of Under-Five Children in Developing Countries. A Systematic Review." *Malawi Medical Journal* 26, no. 4 (December 2014): 115–18. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4325345/.

Merchant, Emily V., Martins Odendo, Norah Maiyo, Ramu Govindasamy, Xenia K. Morin, James E. Simon, and Daniel J. Hoffman. "An Evaluation of Nutrition, Culinary, and Production Interventions Using African Indigenous Vegetables on Nutrition Security among Smallholder Farmers in Western Kenya." *Frontiers in Nutrition* 10 (May 15, 2023). https://doi.org/10.3389/fnut.2023.1154423.

Olney, Deanna K., Abdoulaye Pedehombga, Marie T. Ruel, and Andrew Dillon. "A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso

Reduces Anemia, Wasting, and Diarrhea in Children 3-12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial." *The Journal of Nutrition* 145, no. 6 (June 2015): 1317–24. https://doi.org/10.3945/jn.114.203539.

Roche, Marion L., Grace S. Marquis, Theresa W. Gyorkos, Brittany Blouin, Julieta Sarsoza, and Harriet V. Kuhnlein. "A Community-Based Positive Deviance/Hearth Infant and Young Child Nutrition Intervention in Ecuador Improved Diet and Reduced Underweight." *Journal of Nutrition Education and Behavior* 49, no. 3 (March 1, 2017): 196-203.e1. https://doi.org/10.1016/j.jneb.2016.10.007.

Roy SK, Fuchs GJ, Mahmud Z, Ara G, Islam S, Shafique S, Akter SS, Chakraborty B. Intensive nutrition education with or without supplementary feeding improves the nutritional status of moderately-malnourished children in Bangladesh. J Health Popul Nutr. 2005 Dec;23(4):320-30. PMID: 16599102.

Schroeder, Dirk G., Helena Pachón, Kirk A. Dearden, Tran Thu Ha, Tran Thi Lang, and David R. Marsh. "An Integrated Child Nutrition Intervention Improved Growth of Younger, More Malnourished Children in Northern Viet Nam." *Food and Nutrition* Bulletin 23, no. 4_suppl2 (December 1, 2002): 50–58. https://doi.org/10.1177/15648265020234S208.

Shi, Ling, Jingxu Zhang, Yan Wang, Laura E. Caulfield, and Bernard Guyer. "Effectiveness of an Educational Intervention on Complementary Feeding Practices and Growth in Rural China: A Cluster Randomised Controlled Trial." *Public Health Nutrition* 13, no. 4 (April 2010): 556–65. https://doi.org/10.1017/S1368980009991364.

Vazir, Shahnaz, Patrice Engle, Nagalla Balakrishna, Paula L. Griffiths, Susan L. Johnson, Hilary Creed-Kanashiro, Sylvia Fernandez Rao, Monal R. Shroff, and Margaret E. Bentley. "Cluster-Randomized Trial on Complementary and Responsive Feeding Education to Caregivers Found Improved Dietary Intake, Growth and Development among Rural Indian Toddlers." *Maternal & Child Nutrition* 9, no. 1 (2013): 99–117. https://doi.org/10.1111/j.1740-8709.2012.00413.x.

2. Cooking classes

Cooking classes teach households how to prepare foods to improve the nutritional content of meals. Only two papers met our inclusion criteria, but both papers studied the impact of cooking classes as one component within a larger bundle of nutrition education interventions. Cooking classes may also appear as components of nutrition campaigns and home gardens, covered in earlier sections. In low-income settings, limited dietary diversity is associated with low nutritional intake, especially among young children. Cooking class interventions offer parents and caregivers nutritional guidance and interactive cooking sessions featuring nutritious ingredients. There is **low evidence** of the impacts of cooking classes on food and nutrition security. There is a lack of evidence on agricultural productivity, income, and climate resilience, likely because these are not typical outcomes for this category of interventions
.
In Ecuador, participants were invited to 12 sessions of cooking classes and nutrition education led by peers (Roche et al., 2017). Dietary diversity and nutrition knowledge increased, and the prevalence of underweight decreased in a 6-month follow-up. In Kenya, participants were invited to 4 sessions initiated by community health workers using a syllabus developed by local nutrition practitioners (Waswa et al., 2015). Dietary diversity and exclusive breastfeeding increased. The study in Kenya was of higher quality and involved a large-scale RCT (Waswa et al., 2015). The study in Ecuador used matching methods and had too few clusters for high-quality inference (Roche et al., 2017).

Cost-effectiveness: Unclear, likely mixed. Cooking classes are often bundled with nutrition campaigns, and it is not clear which components of nutrition campaigns are effective. They need to be tailored to local contexts, which raises fixed costs. Once nutrition curricula are developed, there would be a relatively low marginal cost of adding additional households. Neither study included information about cost-effectiveness. There is also a lack of evidence about the most cost-effective length of cooking classes or delivery format. Both studies used in-person classes, with one using a curriculum that could be scaled to other areas and the second creating a participatory curriculum that involved local peer educators. Both cooking classes emphasized local ingredients that are common in each location and taught preparations that would help young children (under 24 months) access nutrition.

Context: Although evidence about the effectiveness of cooking classes is limited, cooking classes are likely most appropriate in settings where there appears to be a nutrition gap among young children when they transition from breastfeeding so that families can learn how to introduce nutritious foods at a young age.

Roche, Marion L., Grace S. Marquis, Theresa W. Gyorkos, Brittany Blouin, Julieta Sarsoza, and Harriet V. Kuhnlein. "A Community-Based Positive Deviance:Hearth Infant and Young Child Nutrition Intervention in Ecuador Improved Diet and Reduced Underweight." *Journal of Nutrition Education and Behavior* 49 (2017). https://drive.google.com/file/d/19bTAAfA9RSrancFWq0v-UAN-5y4boul3/view?usp=embed_facebook.

Waswa, Lydiah M., Irmgard Jordan, Johannes Herrmann, Michael B. Krawinkel, and Gudrun B. Keding. "Community-Based Educational Intervention Improved the Diversity of Complementary Diets in Western Kenya: Results from a Randomized Controlled Trial." *Public Health Nutrition* 18, no. 18 (December 2015): 3406–19. https://doi.org/10.1017/S1368980015000920.

3. Professional services to promote healthy eating (dietitians/nurses)

This review considers evaluations of programs using dieticians and nurses to promote healthy eating. The interventions aim to address the information gap among adults and caregivers regarding daily dietary needs and micronutrient deficiencies in children. They involve training healthcare professionals to provide parents and caregivers with nutritional information. The goal of employing trained professionals is to improve trust in the information delivered and potentially help reduce the stigma associated with particular foods or practices. There is **low evidence** of the impact of such programs on food and nutrition security outcomes. There is a lack of evidence on agricultural productivity, income, and climate resilience, likely because these are not typical outcomes for this category of interventions.

This review found no evaluations of standalone nutrition education campaigns meeting the inclusion criteria and three evaluations, including behavior change communication (BCC) as part of a broader package. In China, evaluations of health education campaigns for parents that aimed to reduce iron-deficiency anemia among primary school students in rural China found modest impacts on anemia, but only when training was paired with iron supplementation (Luo et al., 2012). In Bangladesh, adding nutrition behavior change communication led by trained nutrition workers increased the impact of a cash transfer on recipients' consumption and assets (Ahmed et al., 2019). In Ethiopia, a nutritionist delivered behavior change communication as part of a community poultry intervention to promote egg and eggshell powder consumption by young children (Omer et al., 2018). Poultry production and egg consumption increased, but the study does not isolate the impact of the BCC from the gifting of chickens to families.

Cost-effectiveness: Likely low. There is not enough evidence to suggest a positive effect of hiring dieticians/nurses for nutrition campaigns. It would likely be more expensive to train and hire professionals compared to community-based nutrition interventions. A literature review on community health workers (CHWs) in health programs in lower- and middle-income countries notes that CHWs are relatively more cost-effective for tuberculosis, reproductive, maternal, newborn, and child health than standard care delivered by doctors and nurses (Vaughan et al., 2015).

Ahmed, Akhter, John Hoddinott, Shalini Roy, and Esha Sraboni. "Transfers, Nutrition Programming, and Economic Well-Being Experimental Evidence from Bangladesh." *IFRI*, 2019. https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/133450/filename/133662.pdf.

Luo, R., Y. Shi, L. Zhang, H. Zhang, G. Miller, A. Medina, and S. Rozelle. "The Limits of Health and Nutrition Education: Evidence from Three Randomized-Controlled Trials in Rural China." *CESifo Economic Studies* 58, no. 2 (June 1, 2012): 385–404. https://doi.org/10.1093/cesifo/ifs023.

Omer, Anteneh, Demmelash Mulualem, Henry Classen, Hassanali Vatanparast, and Susan Whiting. "A Community Poultry Intervention to Promote Egg and Eggshell Powder Consumption by Young Children in Halaba Special Woreda, SNNPR, Ethiopia." *Journal of Agricultural Science* 10 (April 11, 2018): 1. https://doi.org/10.5539/jas.v10n5p1.

Vaughan, Kelsey, Maryse C. Kok, Sophie Witter, and Marjolein Dieleman. "Costs and Cost-Effectiveness of Community Health Workers: Evidence from a Literature Review." *Human Resources for Health* 13, no. 1 (September 1, 2015): 71. https://doi.org/10.1186/s12960-015-0070-y.

Appendix

Table 1: Literature review inclusion criteria

Search Criteria		
Item	**Inclusion**	**Exclusion**
Outcomes of interest	• Food consumption score • Dietary diversity • Nutrition status and anthropometry • Incomes • Agricultural productivity, production, and revenue	N/A
Target groups	• Poor/food insecure households • Children under 2 • Children under 5 • Pregnant or lactating mothers	N/A
Target settings	• Fragile contexts (as classified 2006>)	N/A
Publication status	• Publicly available publications	Publications linked only to authors' websites or not publicly available
Publication Type	• Peer-reviewed articles • Academic working papers	Reports, policy memos, books, dissertations, briefs, and theses not meant for publication in a peer-reviewed journal
Study design	• Randomized controlled trials (RCT) • Natural experiments with well-identified causal designs	Observational studies Studies without a clear causal design
Locations	• Studies from LMICs (as classified 2000>)	Studies from HICs
Language	• English	Papers published in other languages
Publication year	• 2000 onwards	Studies published before 2000